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Maumee River Basin Pilot Watershed Study Volume I. Watershed Characteristics and Pollutant Loadings, Defiance Area, Ohio

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Columbus

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Maumee River Pilot Watershed Study

Watershed Characteristics And Pollutant Loadings

Defiance Area, Ohio

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The United States Environmental Protection Agency was created because of increasing public and governmental concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment.

The Great Lakes National Program Office (GLNPO) of the U.S. EPA, was established in Region V, Chicago to provide a specific focus on the water quality concerns of the Great Lakes. GLNPO provides funding and personnel support to the International Joint Commission activities under the US-Canada Great Lakes Water Quality Agreement.

Several land use water quality studies have been funded to support the Pollution from Land Use Activities Reference Group (PLUARG) under the Agreement to address specific objectives related to land use pollution to the Great Lakes. This report describes some of the work supported by this Office to carry out PLUARG study objectives.

We hope that the information and data contained herein will help planners and managers of pollution control agencies make better decisions for carrying forward their pollution control responsibilities.

Dr. Edith J. Tebo
Director
Great Lakes National Program Office

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The phosphorus, sediment transport, heavy metals, and pesticide studies are discussed in Volume 2 of this report.

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Volume I
Watershed Characteristics and Pollutant Loadings

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Monitoring during 1975-1977 showed that there were significant differences in sediment and nutrient losses among different soil types in the Basin. Greatest sediment losses occurred on the level and very poorly drained, high-clay lake plain soils as well as the sloping, dissected lake plain clay soils. Losses were intermediate on moderately sloping, till-plain soils and very low on level soils with good internal drainage characteristics when they are tile-drained. Comparison with larger drainage areas in the Basin showed that snow melt and frontal spring storms resulted in significant sediment and nutrient movement across the entire Basin on large and samll watersheds, while summer convective storms were localized and had less effect on downstream pollutant loads.

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1. SUMMARY

The results of this study produced a number of important findings about pollution from land use in the Maumee River Basin and re-emphasized what we already knew:

1. The Basin is made up of fine-textured soils of high natural fertility that produce sediment during runoff in relation to their slope, internal drainage, and susceptibility to sediment transport.

2. Most of the Basin (~ 70%) is in intensive row-crop agriculture where, for the most part, the soils are fall-plowed and are bare from November to June.

3. Much of the agricultural land is drained by subsurface tile or surface drains and is served by a vast network of man-made or modified ditches.

4. The period of active sediment transport is in late winter or early spring and the severity of erosion and sediment transport is determined by soil moisture and snow-melt conditions during initial thaw.

5. Phosphorus is the major pollutant from the Maumee River Basin, and the high phosphate content of suspended sediments reflects the high P levels in Basin soils and the enrichment of P in sediment due to clay enrichment during transport and adsorption of soluble P in the stream.

6. Levels of pesticides and trace metals in the Maumee River were low and reflect background levels in Basin soils and normal metal contributions from groundwater.

2. IMPLICATIONS FOR REMEDIAL MEASURES AND RECOMMENDATIONS

The efficiency of a particular remedial measure, "best management practice," or conservation practice in reducing the contribution of pollution to the Great Lakes from land runoff must be considered from a variety of viewpoints. There is a fairly well-developed body of knowledge regarding the reduction in gross erosion, which may be obtained through the use of a particular practice. Although there is some uncertainty among scientists as to the absolute efficiency of the different practices, the "C," cropping management, and "P," erosion control practice, factors of the Universal Soil Loss equation which have been extensively compiled by the Soil Conservation Service, USDA, can give an excellent idea of the relative efficiency of the different combination of land management systems that can be used by farmers to reduce gross erosion.

On the other hand, our knowledge of how these practices alter the sediment--and pollutant and nutrient--delivery ratio is still seriously lacking. Several studies have indicated that the delivery ratio, i.e. sediment actually delivered to drainage ways divided by gross erosion, is significantly decreased by the application of some management practices. This is primarily because some practices are most efficient in reducing the movement of relatively larger-size soil particles. The resultant runoff, enriched with fine particles, can move much further than the larger particles. It is also well known that the fine particle-size fraction is the fraction which carries with it most of the particulate adsorbed bio-available phosphorus. As a result an erosion control practice, which is efficient in reducing gross erosion, may be less efficient in reducing delivery of phosphorus to the Great Lakes. Considerably more research will be necessary before it can be determined how efficient a management practice is in reducing phosphorus loadings relative to gross erosion. It must be borne in mind, though, that a management practice which produces a 50% reduction in gross erosion will also produce a significant reduction in phosphorus loading, probably on the order of 25 to 40%, or 50 to 80% of the reduction in gross erosion.

Another aspect of the effectiveness of BMPs is the cost per unit area of application per unit of pollutant reduction. The cost must be assessed against the particular pollutant most important to the Great Lakes, i.e. phosphorus. The above discussion of practice efficiency again becomes important. Consider, for example, the installation of grassed waterways. This is a practice designed primarily to abate gully erosion in areas of concentrated runoff. In gully erosion the principal erodant is subsurface soil that is generally low in phosphorus, which is considered to be bio-available. So, this practice does little to reduce phosphorus pollution to the Great Lakes. At the same time, it is extremely important to the farmer, because it prevents the ruination of his fields by gully formation.

For another example, consider the installation of parallel terraces with tile outlets (PTOs). A PTO installation consists of a series of berms of soil constructed across the swale, relatively closer together or farther apart depending on the length and degree of the slope across which they are constructed. A tile line is laid along the bottom of the swale beginning just behind the highest berm. Behind each berm a vertical tile is connected to the main tile and extending to the height of the berm above ground level. The vertical tile is perforated so that water may enter it and flow through a control orifice into the main tile to a drainageway at the bottom of the slope. The PTO serves the same function as the grassed waterway in eliminating gully erosion, but it serves a function which the grassed waterway cannot. Because flow is restricted at the vertical tile outlet, water is ponded behind the berm and phosphorus-bearing sediment can be settled out. The grassed waterway cannot perform this function.

The initial cost of the PTO is higher than the grassed waterway but in the long-term may cost less. Maintenance costs may be less for the PTO. More importantly, very little land is taken out of production--only about 50 square feet around the vertical tile, while the entire length of the waterway is out of production. Also, especially important to contour plowing, there is no obstacle to continuous operation of machinery across the slope.

Another management practice which may be of great importance to diffuse source pollution control, but which has previously been considered only as a production enhancement practice, is the installation of underground tile drainage. The Pilot Watershed Study in the Maumee River basin has shown evidence that in areas of flat, poorly drained soil sediment and nutrient yields may be reduced significantly by the installation of tile drainage. Further, tile drainage reduces moisture levels in imperfectly drained soils and improves the moisture retention capacity of the soil. This factor will cause attenuation of runoff during storms. Peak velocities that cause streambank erosion should also be reduced. Another factor for the use of tile is the fact that the no-tillage crop management system may be employed on a greatly enlarged list of soil types when tile drainage is employed.

Also, the increased production obtained through the use of tile will offset many of the costs of other conservation practices which must be employed. While it is too early to assess how much of an impact tile drainage may have on diffuse source pollution reduction, it is becoming evident that it will be an important BMP for poorly drained high clay watersheds. A low level of cost-sharing should be sufficient to increase the installation of tile.

2.1 Recommendations for Maumee River Basin

1. Point source reduction of P should continue to be pursued, especially for Toledo because of its high delivery to the Western Basin of Lake Erie.

2. Heavy metals and pesticides are not a problem at the present time, but pesticides in water and sediment should be periodically scanned to identify any new compounds or other toxic organics which may come on the scene in the future.

3. Conservation practices should be accelerated to reduce erosion on the cultivated sloping soils of the Basin. These include the Morley soils with slopes > 6% or better in the till plain regions of the Basin and the Roselms soils with 2-6% slopes in the lake plain region.

4. Maximum sediment load occurs in the period January - March, and, therefore, conservation practices should maximize residue cover during that period. No-till should be recommended on the well-drained Morley soils and chisel plow on the Roselms.

5. Gully erosion is common on the dissected upland soil associations such as Morley-Blount and Roselms. Grassed waterways with or without tile drainage is recommended for these critical areas.

6. Grass buffer strips between field boundaries and drainage ditches are recommended in the Maumee because of the large network of drainage ditches in the Basin. This recommendation is especially important in the lake plain region, where ditches are more numerous and the soils are high in clay.

7. Reduced tillage can not be justifiably recommended on the level (A slope) soils of the Basin because of their low soil loss and the crop management difficulties associated with reduced tillage on these soils. However, subsurface (tile) drainage appears to reduce runoff and soil loss on these soils in addition to improving crop production. Therefore, accelerated tile drainage installation is recommended on the level, poorly drained soils of the Basin.

8. The Paulding soil is very high in clay and possesses low hydraulic conductivity; as a result, tile drainage is not recommended on this soil. Further research is needed to develop acceptable crop management (including drainage) practices which will maintain crop productivity and reduce soil loss and transport.

9. Soils in the Maumee are high in clay, relatively high in total P, and, because of its high clay content, the suspended sediment is enriched in total P. Plant-available P levels in watershed soils are generally adequate for maximum crop production. Educational programs should stress the importance of following soil test recommendations, and soil fertility research is needed to better define sufficiency levels of available P in soil.

2.2 General Recommendations for the Great Lakes

1. Point source phosphorus reductions must be continued with emphasis on those discharges which are on the lake shore and on main stem tributaries.

2. Soil-loss reductions from intensively cultivated cropland should be accelerated with emphasis on the medium and fine textured soils on sloping land. The critical area concept should be on a soil-type basis, utilizing both erodibility (Universal Soil Loss Equation "k" factor) and transportability (percent clay) as determinants.

3. Cropland erosion control should be geared to the period (season) of maximum erosion and transport. In much of the Great Lakes region this period is from January through April. Residue management to keep the soil in place is likely to be more effective than measures to reduce sediment transport, especially on the finer soils.

4. Phosphorus fertilizer and manure management should more accurately reflect crop requirements and soil-test levels. Summaries of soil test results should be used to monitor available nutrient levels in regions of intensive cultivation.

5. Modeling should proceed to determine the degree of soluble, available and total P reduction that might be attained per unit of sediment reduction.

6. A tributary monitoring program should be developed to periodically scan water and sediment for toxic chemical discharges.

3. INTRODUCTION

The Maumee River was chosen by PLUARG to be one of four pilot watersheds to be studied on the U. S. side of the Great Lakes drainage basin as part of Task C - pilot watershed studies. Since there was already an ongoing PL-92-500 Sec. 108 demonstration project in Black Creek basin, an Indiana tributary to the Maumee, the Task C project was directed to the Ohio portion of the Maumee to supplement the work being done in Black Creek.

The objectives of PLUARG are to determine the effects of prevailing land use practices on pollution entering the Great Lakes. Specifically, the PLUARG Task C objectives are to answer the following questions:

1. From what sources and from what causes (under what conditions, management practices) are pollutants contributed to surface and ground water?

2. What is the extent of pollutant contributions and what are the unit area loadings by season from a given land use or practice to surface or ground water?

3. To what degree are pollutants transmitted from sources to boundary waters?

4. Are remedial measures required? What are they and how effective might they be?

5. Were deficiencies in technology identified? If so, what is recommended?

As we will see later, the Maumee River Basin is primarily agricultural in land use, and studies by the U. S. Army Corps of Engineers (1975) and the Great Lakes Basin Commission (1978) have indicated that diffuse sources account for about 75% of the phosphorus and nitrogen entering Lake Erie from the Maumee. Because of the previous monitoring efforts on the Maumee by the Corps of Engineers, it was decided to place emphasis in the Task C project on soil and nutrient loss from small agricultural watersheds and on specialized studies on sediment transport.

Specific objectives of this study are:

1. To determine the effects of land-use practices on the loss of sediment and associated chemicals from representative small agricultural watersheds in the Basin and to compare these data with downstream reference samples.

2. To study and determine the physical, chemical, and mineralogical properties of major soils in the Basin and relate these data to their susceptibility to erosion and fluvial transport.

3. To determine the physical, chemical, and mineralogical properties of suspended sediments and bottom sediments in order to identify fluvial transport mechanisms and to evaluate equilibrium stabilities of minerals in suspended and bottom sediments.

4. To determine phosphate sorption-desorption and precipitation interactions with sediment characteristics and concentration levels.

5. To determine heavy metals leaving small agricultural watersheds as contrasted to downstream reference sources.

This report presents the findings of our studies in the period 1975-77. It will draw on the research of other workers in the Maumee to give as complete a picture as possible.

3.1 Study Approach

The basic approach of this study was to measure the generation of sediment and nutrients from intensively cultivated cropland under prevailing management practices and to compare these losses with the yield of the same materials at the downstream discharge point. The study investigated the differences in pollutant generation on several of the major soils of the Maumee Basin and determined the effects of season and soil characteristics on sediment and nutrient generation. Pollutant transport by tile drainage was also studied because of the extensive use of underground tile for drainage in the Basin.

The chemical and mineralogical nature of suspended and bottom sediments was studied and compared to the soils of the Basin in order to better understand the changes in sediment during fluvial transport.

Levels of heavy metals in soil, sediment and surface and ground water were surveyed throughout the Basin; pesticides in sediment were also scanned.

Yields of sediment and nutrients from the Black Creek Sec. 108 study in Allen County, Indiana were used for comparison with those from the small plots studied in Ohio and the downstream yields at Waterville (approximately 90% of the drainage basin).

3.2 Study Methods

The basic approach of this study was to measure sediment and nutrient loss from small agricultural watersheds and plots on major soils in the Maumee River Basin and compare these losses with those from larger areas in the Basin.

Five sites were chosen in Defiance County on four major soils of the Basin (Figure 1 and Table 1) ranging from 0.6 to 3.2 hectares in area. Surface runoff was monitored at all sites and tile drainage on the Lenawee, Paulding and Blount sites. A continuous-flow monitoring system and integrated sampler were used so that all events were monitored and sampled. The sampling period was from May 1975 - May 1977. All sites were fall-plowed and planted to soybeans, so differences in sediment and nutrient loss are a function of soil differences. Rainfall was monitored at each site. At the OARDC branch research station in Wood County, eight plots (0.04 ha) on Hoytville soil were subjected to a number of different tillage treatments, and runoff and tile drainage were monitored. Sediment and nutrient loading data were obtained from two other study areas in the Maumee, the Black Creek Sec. 108 study in Allen County, Indiana and the monitoring study by Heidelberg College at Waterville, Ohio on the main stem of the Maumee (Figure 1). Similar data were also obtained from the Portage River TMACOG Sec. 208 study. The Portage River Basin is adjacent to the Maumee and has similar land use.

The drainage areas of the various study sites vary from 0.04-3.2 hectares for the Ohio Task C study to 735 to 890 hectares in the Black Creek study, 1109 km^2 in the Portage, and 17,058 km^2 at Waterville. Comparison of unit area sediment and nutrient losses from these areas will give some indication of delivery ratio, and a comparison of monthly losses will indicate active runoff periods on the upland landscape as well as for the whole Basin.

Table 4 describes the data sets used in this study as obtained from the studies described above. The data pertaining to the Black Creek Watersheds are from Purdue University (Black Creek Report, 1977). The data for the Maumee River at Waterville and the Portage River at Woodville were obtained from the River Studies Laboratory at Heidelberg College, Tiffin, Ohio. The River Studies Laboratory performed all sampling and laboratory analysis for both the USACOE and TMACOG. The sampling for both programs were performed in exactly the same fashion differing only in the time period of performance. Sampling was continuous from January 1975 to June 1977 (the period covered in this report), and is continuing.

FIGURE 1. SAMPLING SITES IN THE MAUMEE RIVER BASIN.

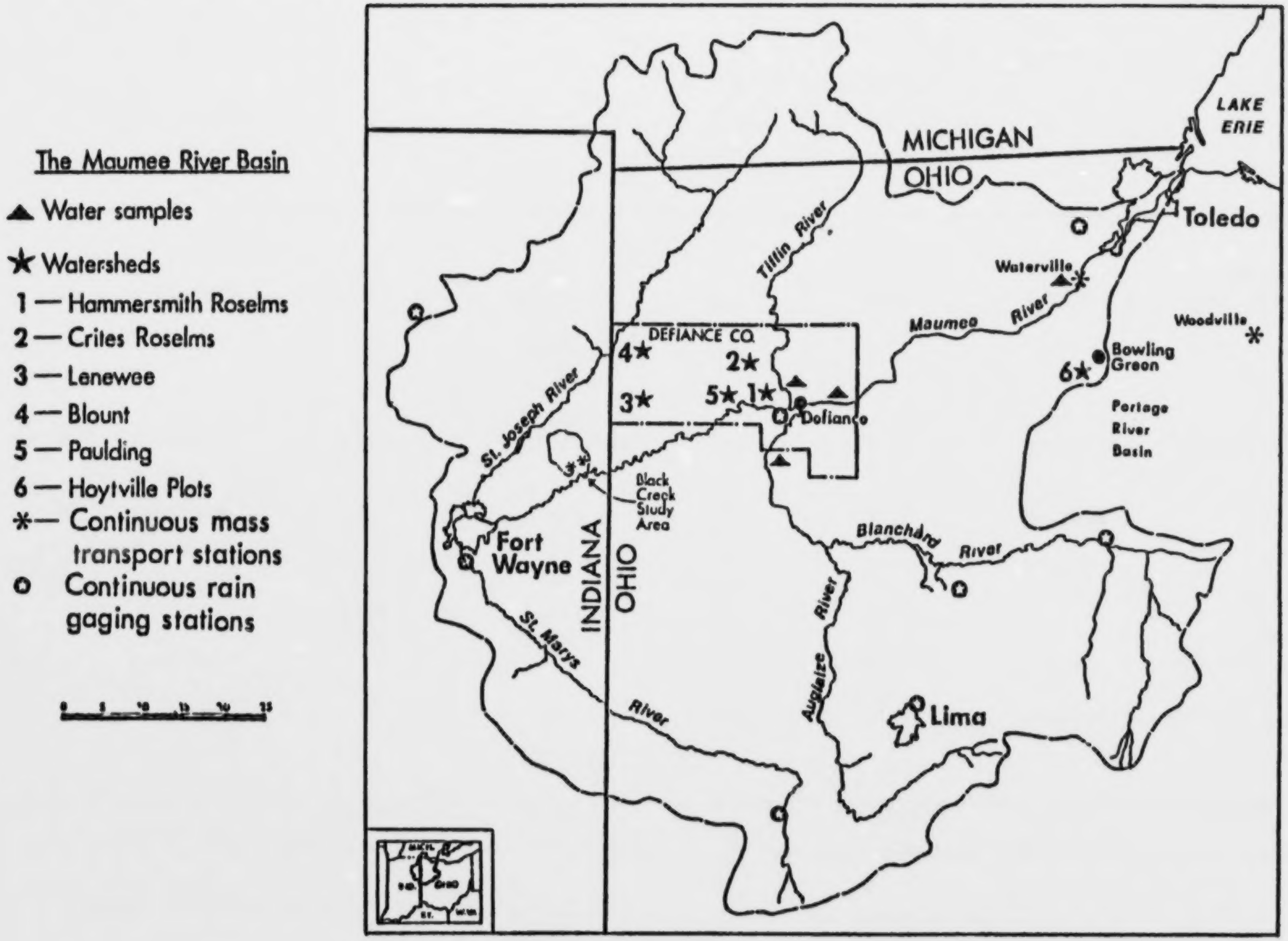
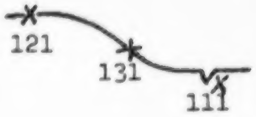

The Maumee River Basin
▲ Water samples
★ Watersheds
1 — Hammersmith Roselms
2 — Crites Roselms
3 — Lenewee
4 — Blount
5 — Paulding
6 — Hoytville Plots
* — Continuous mass transport stations
○ Continuous rain gaging stations
0 5 10 15 20 25
MICHIGAN
OHIO
INDIANA
OHIO
LAKE ERIE
Toledo
Waterville
Woodville
Bowling Green
Portage River Basin
Maumee River
Tiffin River
DEFIANCE CO.
Defiance
St. Joseph River
Black Creek Study Area
Fort Wayne
St. Marys River
Blanchard River
Auglaize River
Lima

TABLE 1. SUMMARY OF WATERSHED SITES AND PLOTS.

CODE	DOMINANT SOIL	PHYSIOGRAPHIC REGION	GEOLOGIC MATERIALS	SLOPE (%)	HECTARES	DRAINAGE SYSTEM	REMARKS
			DEFIANCE COUNTY				
111	Roselms	Lake Plain	Lake Clays	3-15	3.2	Surface	Complex Slopes
201	Roselms			3-5	0.6	Surface	
301 & 302	Lenawee			< 1	0.8 0.1	Surface & Tile	
501 & 502	Paulding			1	1.0	Surface & Tile	
401 & 402	Blount	Till Plain	Clay Loam Till	3-4	0.9	Surface & Tile	Dissected Uplands
			WOOD COUNTY				
611 to 682	Hoytville	Lake Plain	Clay Till	< 1	0.04	Surface & Tile	OARDC Drainage Plots

Physical, chemical and mineralogical characteristics of major soils in the Basin, as well as suspended and bottom sediments, were determined to better understand how soil is eroded and transported and the changes that sediment undergoes during fluvial transport. In particular, the chemistry of soil and sediment phosphorus was studied to determine how soluble P is adsorbed and/or desorbed by sediment and the extent to which sediment is enriched with P during erosion and transport.

The concentration of heavy metals in Basin soils, bottom sediments, stream and well water, and bedrock were surveyed to determine major sources of metals in the Basin. Mixing of point source metal discharge with sediment in the river and uptake by stream vegetation was determined by detailed sampling above and below a chromium discharge on the Ottawa River at Lima, Ohio.

The phosphorus, pesticide and metal studies are reported in Volume 2 of this Report and will not be discussed further in this volume.

3.21 Monitoring Sites in Defiance County

Five small agronomic sites were chosen in Defiance County to monitor soil and nutrient loss under prevailing crop management practices. The sites chosen are dominated by a single soil series, and the five sites represent four of the more important series in the Basin: Paulding, Blount, Roselms and Lenawee (similar to Latty). The sites were selected with the following criteria:

1. Topography was typical for that series
2. The watershed was dominated by a single series
3. The watershed could be defined hydrologically
4. There were no septic tank or livestock waste discharges within the watershed
5. Cooperation from the landowner was available
6. Site was accessible from the road, had adequate flow outlet, and electrical service could be brought to the site.

Using these criteria, a large number of sites were examined and five were selected. Table 1 summarizes the site characteristics and Figure 1 identifies their location. A more detailed description of each site is given next. A 3-digit code was used to identify the sites and for identification of samples from each site:

First digit: 1-6 identifies the primary site

Second digit: 0-8 identifies the sub-site within the primary site

Third digit: 102; 1 refers to surface runoff and 2 to tile drainage, which were monitored separately.

Hammersmith Roselms (10X): This site is located in the central area of Defiance County and in the Lake Plain. The soil and plot map is given in Figure 2, and the area is shown in Figure 3. The drainage area is 3.2 ha (8.0 acres) and is composed of Roselms on most of the area with Broughton on the steep slopes. The watershed has well-defined drainage way (Figure 3), and the monitoring system is placed at the point where the drainage way exits the watershed. Slopes vary from 1-3% on the more level part of the watershed to as high as 15% where the landscape breaks into the drainage way. Three monitoring sites were developed on this site, surface drainage of the entire watershed (111) and two small plots, one on top of the slope break (121), the other on the more sloping area (131) which was occupied by Broughton soil. Monitoring was established by summer of 1975. The sub plots were 3 m x 13.3 m (10 ft x 43.5 ft) in area. The subplots were designed to study the relative soil and nutrient loss from two different slope components on the same watershed.

Crites Roselms (20X): This site is located in the north central area of Defiance County in the Lake Plain. The soil and plot map is given in Figure 4. The drainage area is 0.6 ha (1.6 acres) and has a fairly uniform slope (3-5%), with Roselms soil dominating the area. The entire area was monitored for surface runoff (201). The site was considered to be a duplicate for the Hammersmith Roselms site (111) although it does not have as steep slopes. The Roselms soils are the most steeply sloping soils in the Lake Plain and are formed as the drainage cuts its way into the headland, resulting in well-developed channels which are susceptible to gully erosion.

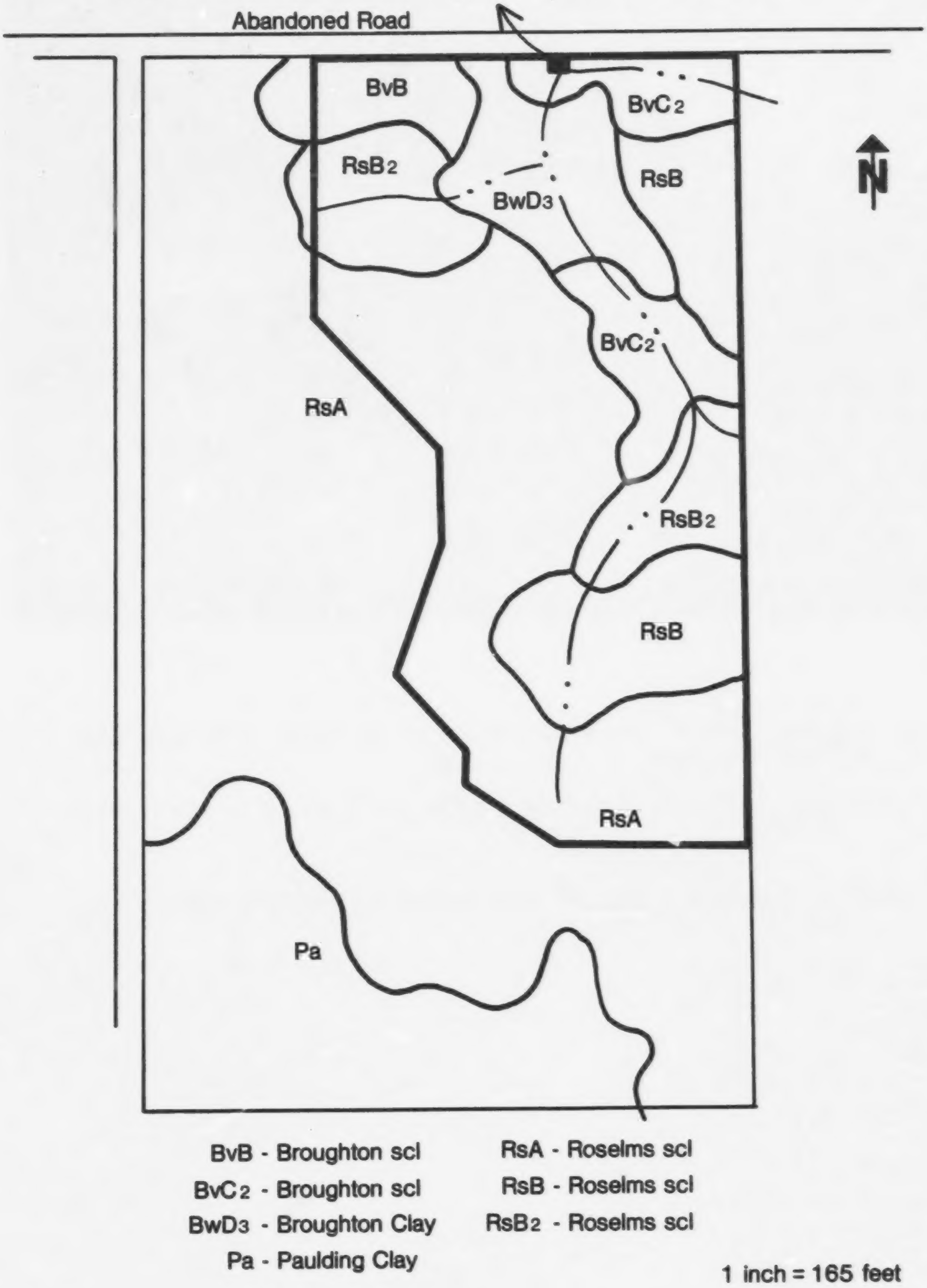
Rohrs Lenawee (30X): This site is located in the western area of Defiance County and near the edge of the Lake Plain. The soil and plot map is given in Figure 5, and the area is illustrated in Figure 6. The area surface drained (301) and monitored is 0.8 ha (2.0 acres) and was outlined by throwing up a berm around the area. The very flat nature of the soils in the area make it impossible to define a natural drainage area. The soils in the plot area are Lenawee and Hoytville over lacustrine clay. In order to study the loss of sediment and nutrients by tile drainage, 3 lines of tile were installed in the plot area. Standard 10 cm (4 inch) diameter corrugated plastic tile was laid by a trencher to a depth of 3 feet. Tile lines were 70 m (250 feet) long and spaced 14 m (50 feet) apart (recommended spacing in the area). The central tile line was monitored, and, by having lines on either side of the one being monitored, the drainage area (0.1 ha, 0.29 acre) could be computed. The tile drainage area was entirely in Lenawee soil.

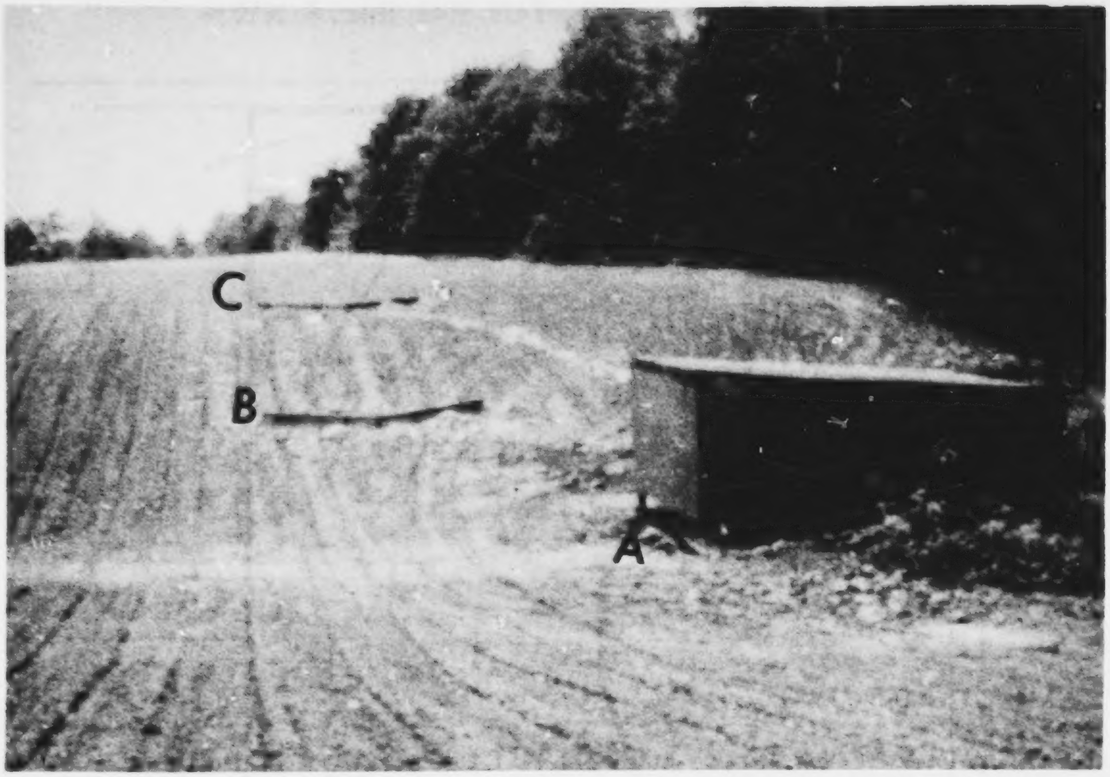
Heisler Blount (40X): This site is located in the northwest corner of Defiance County and is in the till plain region of the Maumee River Basin. The soil and plot map is given in Figure 7 and illustrated in Figure 8. The area is bermed on the upslope perimeter and on the lower side to channel the flow toward the flume. The upper part of the site is Blount loam while the lower end is Mermill loam, which represents the unconsolidated soil eroded from the top of the slope and deposited downslope. The surface drainage area (401) is 0.8 ha (2.1 acres). A previously installed tile system was also monitored (402), and the drainage area has been estimated to be between 2 and 4 acres. The tile drainage pattern shown in the plot diagram (dotted lines) (Figure 7) is only speculative.

FIGURE 2. LAYOUT OF HAMMERSMITH ROSELMS WATERSHED. (HEAVY LINE DENOTES THE MONITORED AREA.)

Hammersmith Roselms (10X)

Location: Noble township, T4N, R48, Sec. 6, NW¼


Abandoned Road
BvB
BvC2
RsB2
RsB
BwD3
BvC2
RsA
RsB2
RsB
RsA
Pa
N
BvB - Broughton scl
BvC2 - Broughton scl
BwD3 - Broughton Clay
Pa - Paulding Clay
RsA - Roselms scl
RsB - Roselms scl
RsB2 - Roselms scl
1 inch = 165 feet



A: Sampling shelter. Front end is open to allow runoff to enter the sediment drop box.

B, C: Component plots on different slope positions, showing the V-shaped flumes.

FIGURE 3. HAMMERSMITH ROSELMS (10X) WATERSHED, DEFIANCE COUNTY, OHIO.

FIGURE 4. LAYOUT OF CRITES ROSELMS WATERSHED (HEAVY LINE DENOTES MONITORED AREA)

Crites Roselms (20X)

Location: Tiffin township, T5N, R4E, Sec. 19, NW¼

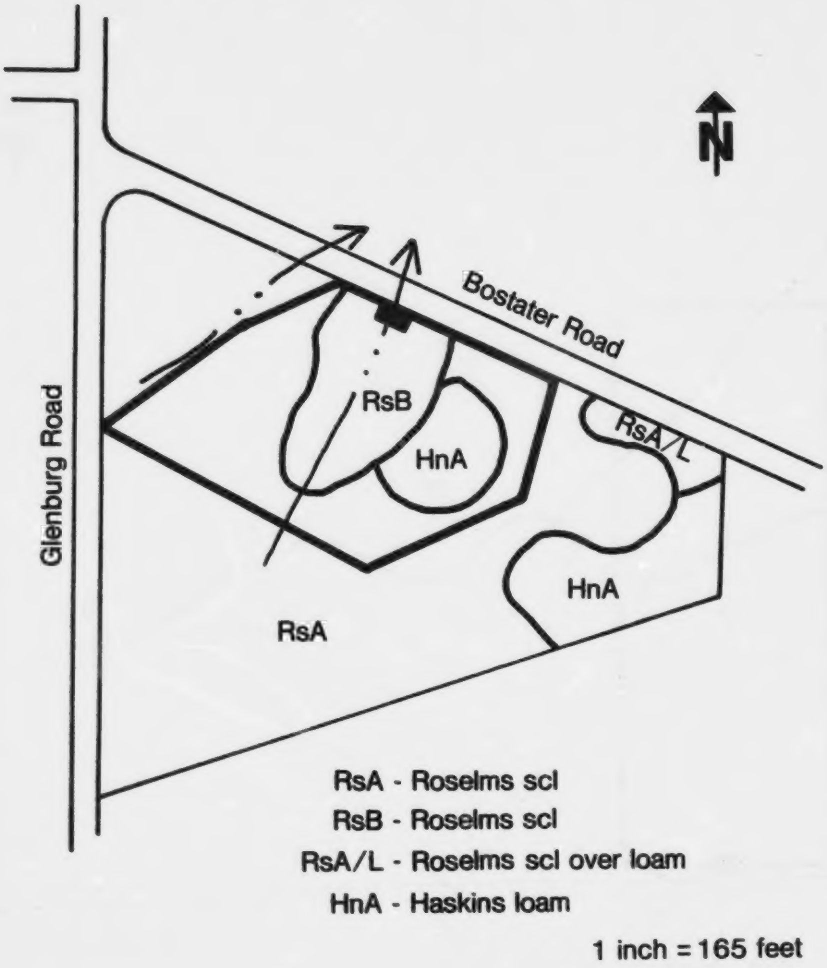

N
Bostater Road
Glenburg Road
RsB
HnA
RsA/L
HnA
RsA
RsA - Roselms scl
RsB - Roselms scl
RsA/L - Roselms scl over loam
HnA - Haskins loam
1 inch = 165 feet

FIGURE 5. LAYOUT OF ROHRS LENAWEE WATERSHED (HEAVY LINE DENOTES MONITORED AREA AND DOTTED LINES ARE TILE)

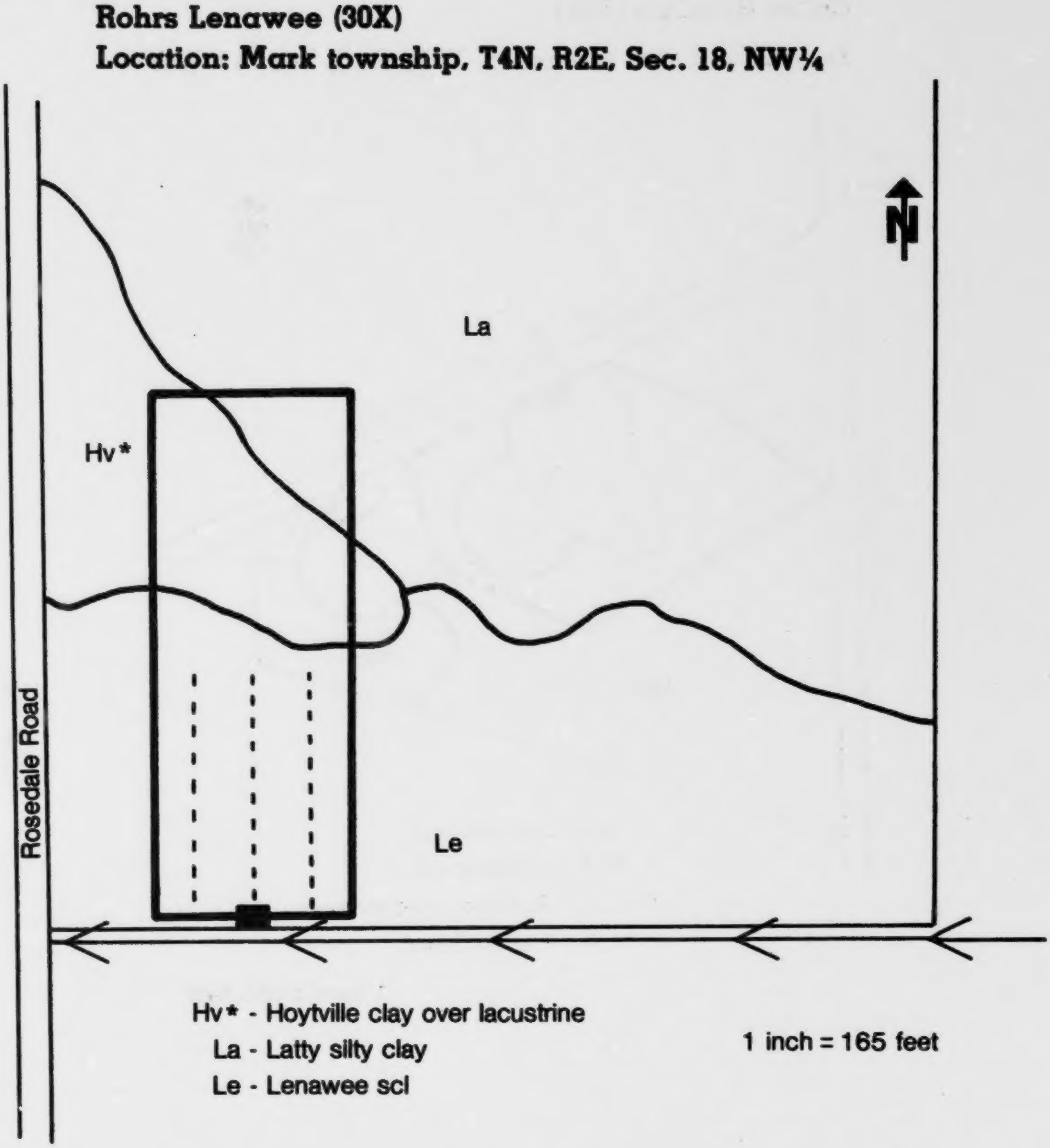

Rohrs Lenawee (30X)
Location: Mark township, T4N, R2E, Sec. 18, NW¼
N
La
Hv*
Le
Rosedale Road
Hv* - Hoytville clay over lacustrine
La - Latty silty clay
Le - Lenawee scl
1 inch = 165 feet

FIGURE 6. LENAWEE (30X) WATERSHED, DEFIANCE COUNTY, OHIO.

FIGURE 7. LAYOUT OF HEISLER BLOUNT WATERSHED (HEAVY LINE DENOTES THE MONITORED AREA AND DOTTED LINES ARE TILE.)

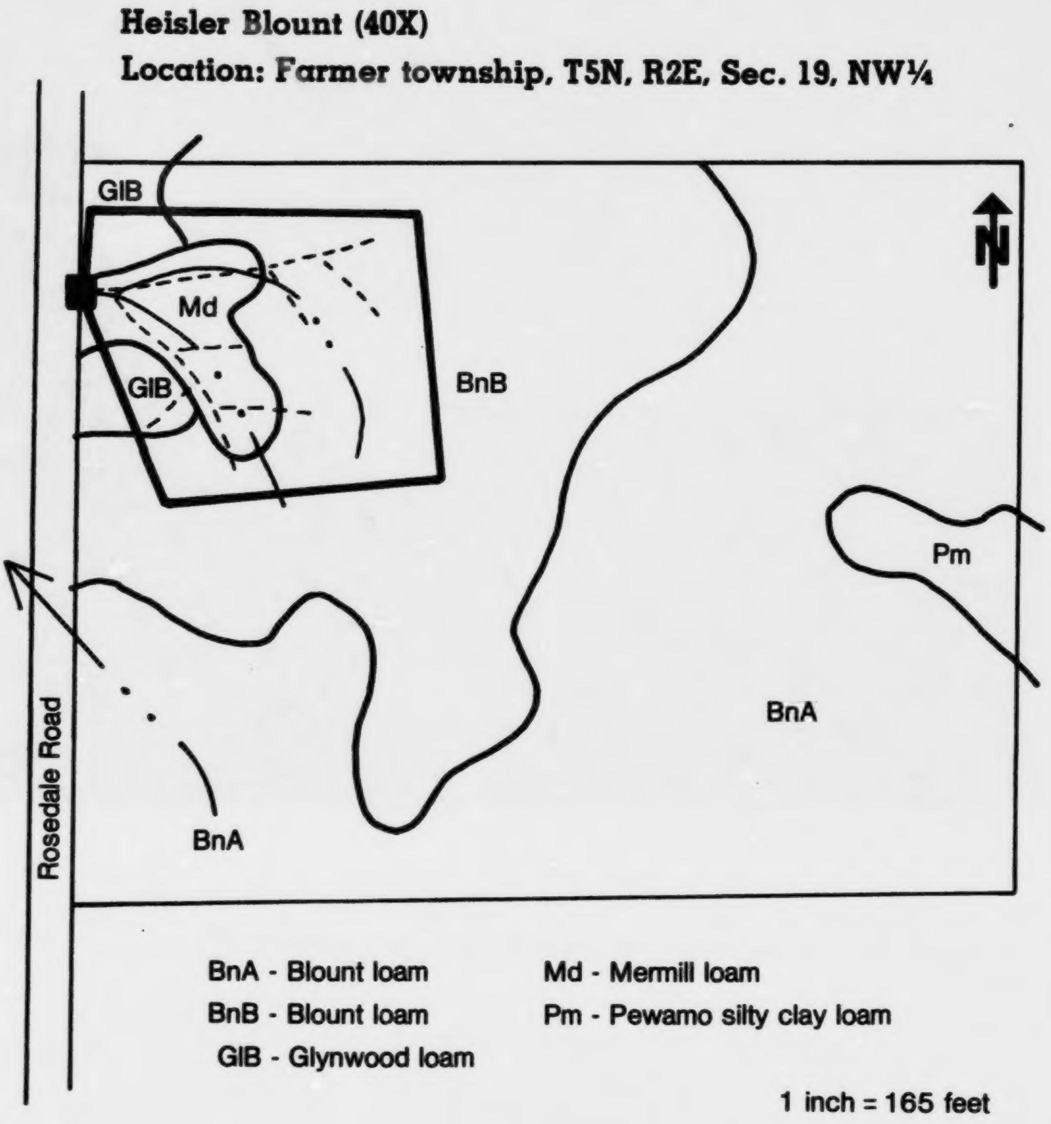

Heisler Blount (40X)
Location: Farmer township, T5N, R2E, Sec. 19, NW¼
GlB
Md
GlB
BnB
N
Pm
BnA
BnA
Rosedale Road
BnA - Blount loam
BnB - Blount loam
GlB - Glynwood loam
Md - Mermill loam
Pm - Pewamo silty clay loam
1 inch = 165 feet

FIGURE 8. BLOUNT (40X) WATERSHED, DEFIANCE COUNTY, OHIO.

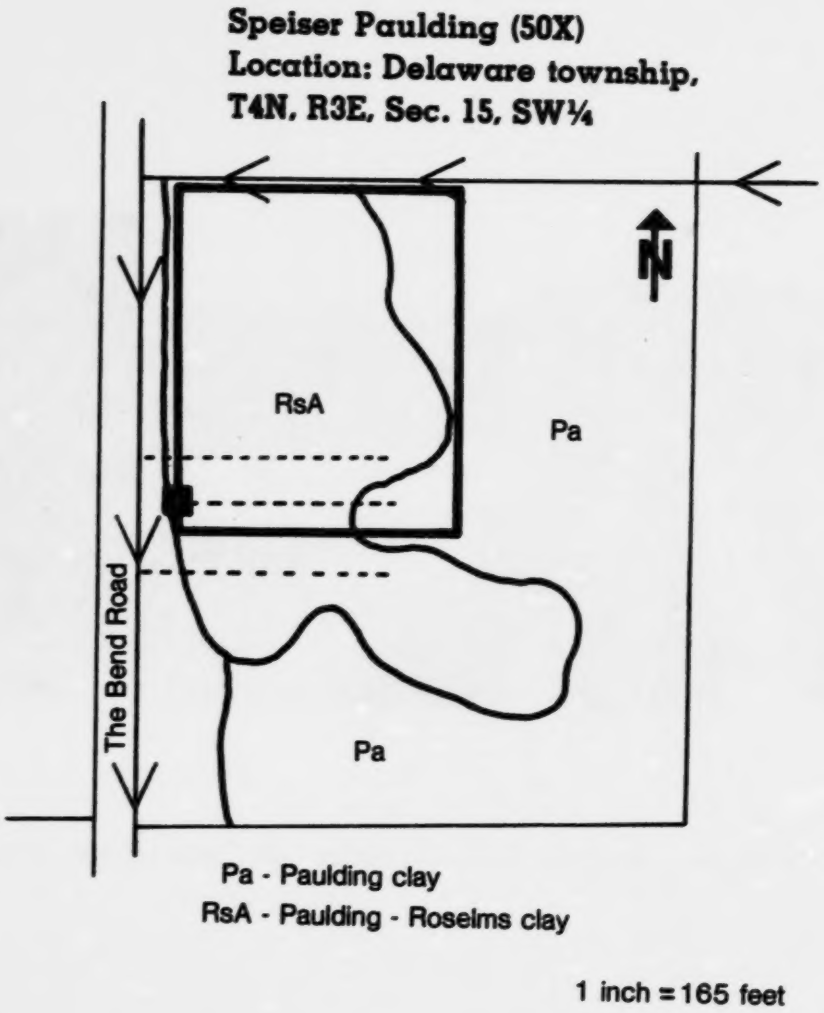
Speiser Paulding (50X): This site is located in the south-central area of Defiance County in the Lake Plain region. The soil and plot map is given in Figure 9 and illustrated in Figure 10 . The major part of the plot is occupied by Paulding-Roselms clay, a series which has all the characteristics of a typical Paulding clay but whose clay content is minimal for Paulding. About a third of the plot is Paulding clay itself. The surface-drained area (501) is 0.9 ha (2.5 acres) and is defined by throwing up a berm,as was done for the Lenawee site. This soil is normally surface-drained by using shallow field ditches, and,in this instance, the ditches were used to carry surface runoff to the sampler. Tile drains were installed in the same manner as for the Lenawee site; the central tile 55.7 m (220 feet) was monitored with a drainage area of 0.09 ha (0.23 acres).

3.22 Surface Runoff and Tile Drainage Measurement - Defiance County Sites

Surface Runoff: It was decided early in the development of this research that sophisticated instrumentation of the sites in Defiance County was not feasible or warranted. A number of physical restraints guided the selection of monitoring devices: both small and large events must be monitored; equipment would have to be automatic because events on small areas are very rapid and the sites had to be serviced by a single technician; it was important to be able to operate in the winter because much of the runoff occurs in the initial storms after thawing in the early spring; there was a general lack of hydraulic head at all sites. The system that was developed had the following basic principle: the runoff was channeled over a drop structure and a known fraction of the flow was intercepted. The intercepted flow was then passed over a Coshocton wheel,which intercepted another fraction. This water then discharged into a sump. A sump pump of known discharge rate (gallons per minute) was activated when water in the sump reached a given level. The pump was connected to a timer,which recorded time of pumping. The water was pumped up into a container from which a sample could be taken. By knowing the fraction of total runoff intercepted and the pump rate and time of pumping, total runoff in a given interval was calculated. The sample taken from the pump discharge represented runoff for that interval. Samples were taken after each event.

A diagram of the equipment used is given in Figures 11 , 12 and 13. Figure 11 shows a standard SCS concrete drop-box, which is used to carry runoff from surface drains to the stream or drainage ditch without causing undue erosion of the bank. A similar structure was used at all five sites in Defiance County. The perimeter of the box was levelled so that flow would be uniform around it. A flume with adjustable vertical slit (Figure 12) was bolted to the front rim of the drop-box. The runoff from the slit fell over a Coshocton wheel (Figure 12) and then from the Coshocton wheel into a sump,which was bolted to the floor of the drop-box (Figure 12). The runoff was pumped by a "Haynes Demon Drainer" submersible pump. This particular model was used because it would pump to near-dryness and this prevented an accumulation of sediment in the sump. Recovery of sediment was tested in the laboratory during the development and calibration of this equipment and was found to be acceptable. The pump was activated by electrodes set to turn on when approximately 0.1 inch of runoff was received. The pump could also be activated manually. The pump was connected to a timer,which could either accumulate pumping time or be reset between events.

FIGURE 9. LAYOUT OF SPEISER PAULDING WATERSHED (HEAVY LINE DENOTES MONITORED AREA AND DOTTED LINES ARE TILE.)


Speiser Paulding (50X)
Location: Delaware township,
T4N, R3E, Sec. 15, SW¼
N
RsA
Pa
The Bend Road
Pa
Pa - Paulding clay
RsA - Paulding - Roselms clay
1 inch = 165 feet

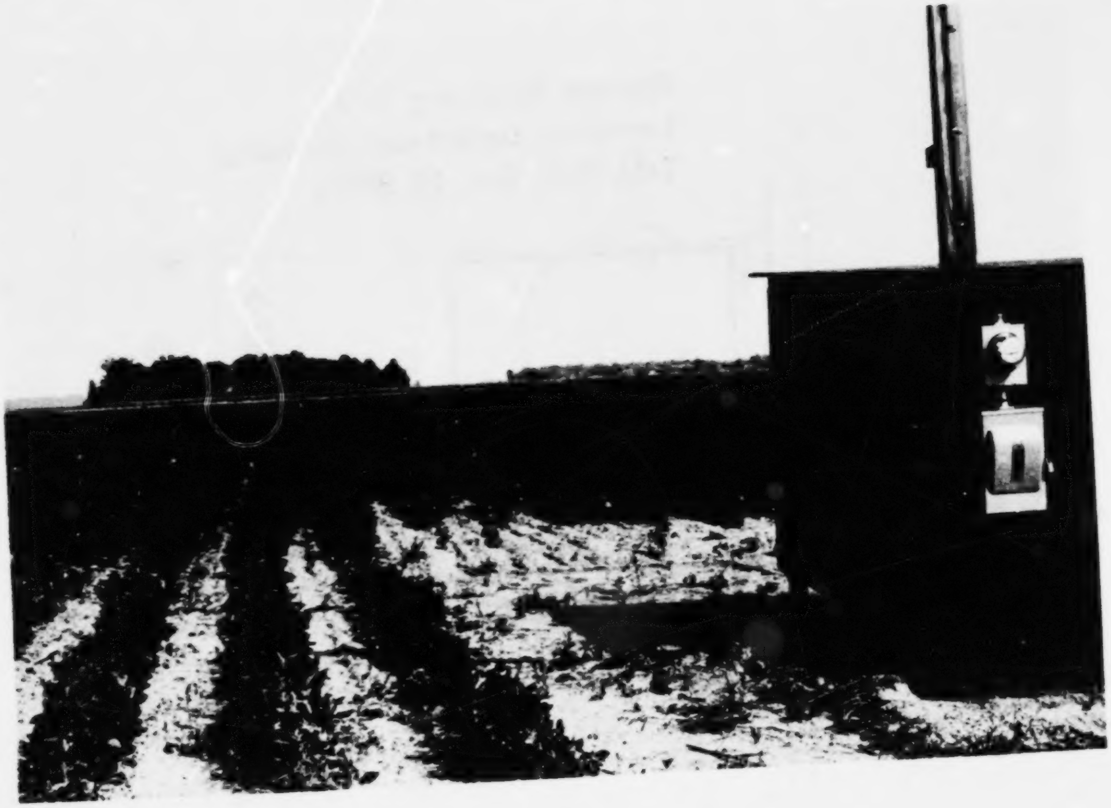


FIGURE 10. PAULDING (50X) WATERSHED, DEFIANCE COUNTY, OHIO.

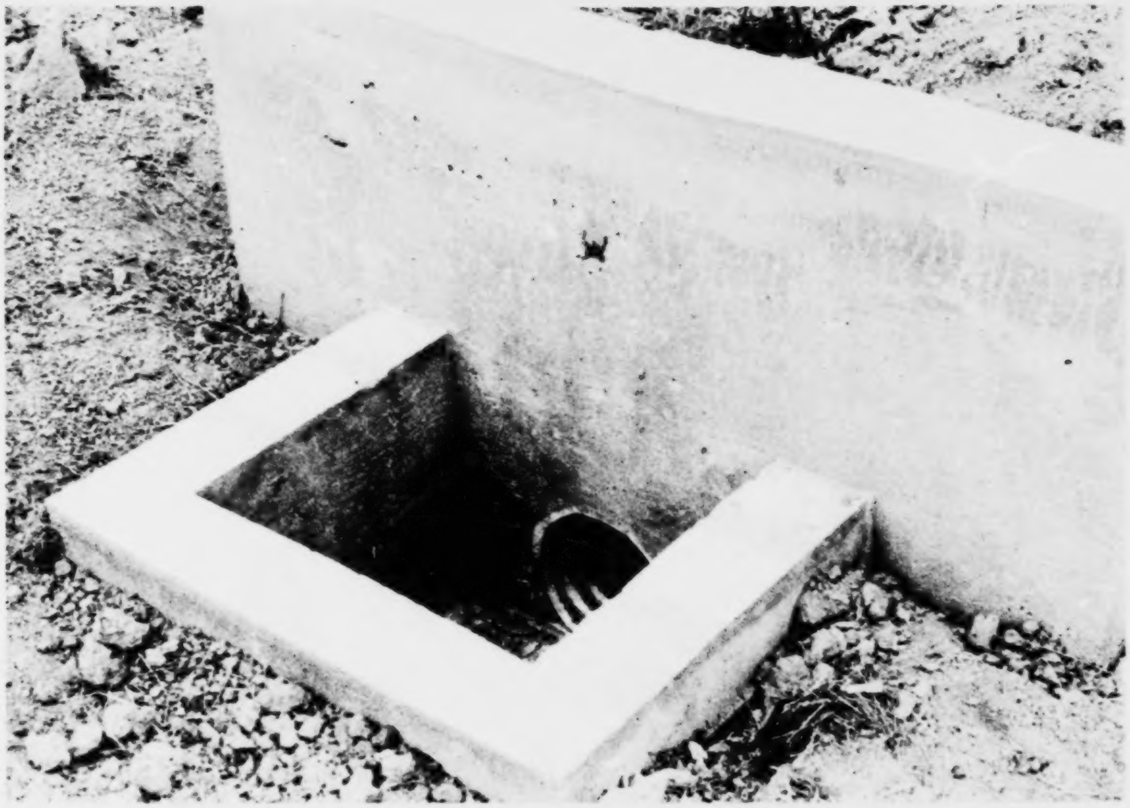
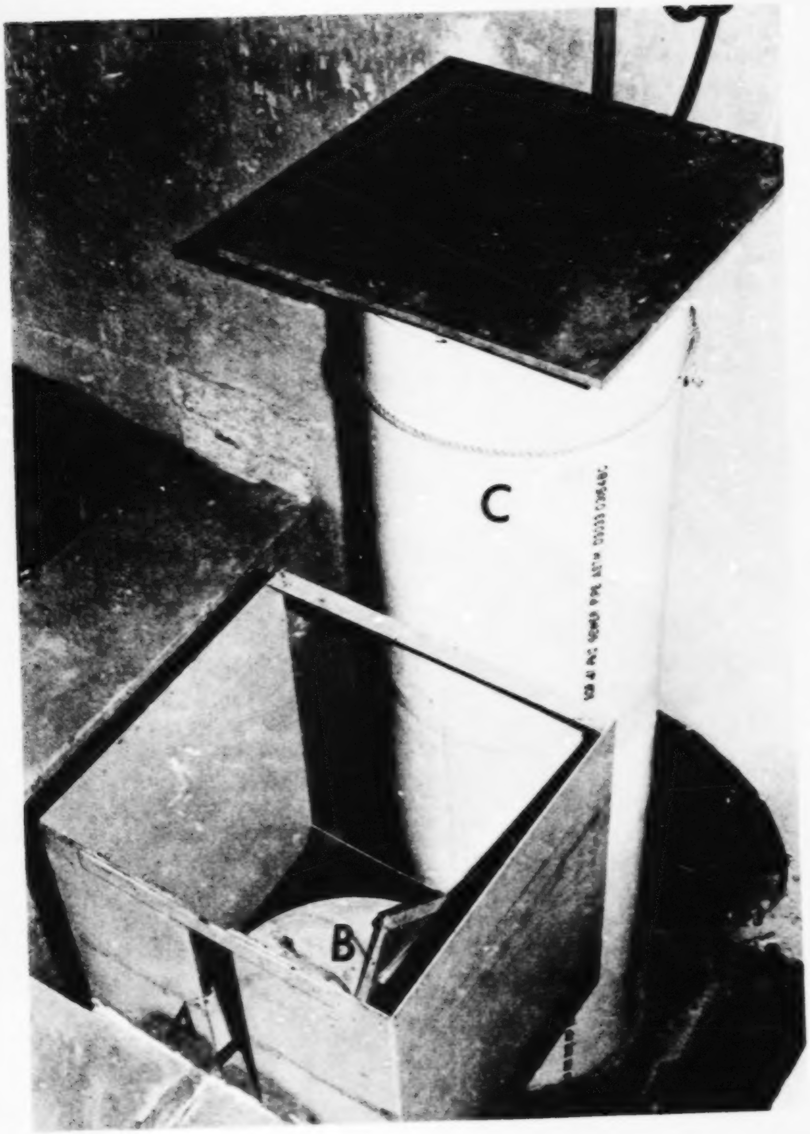


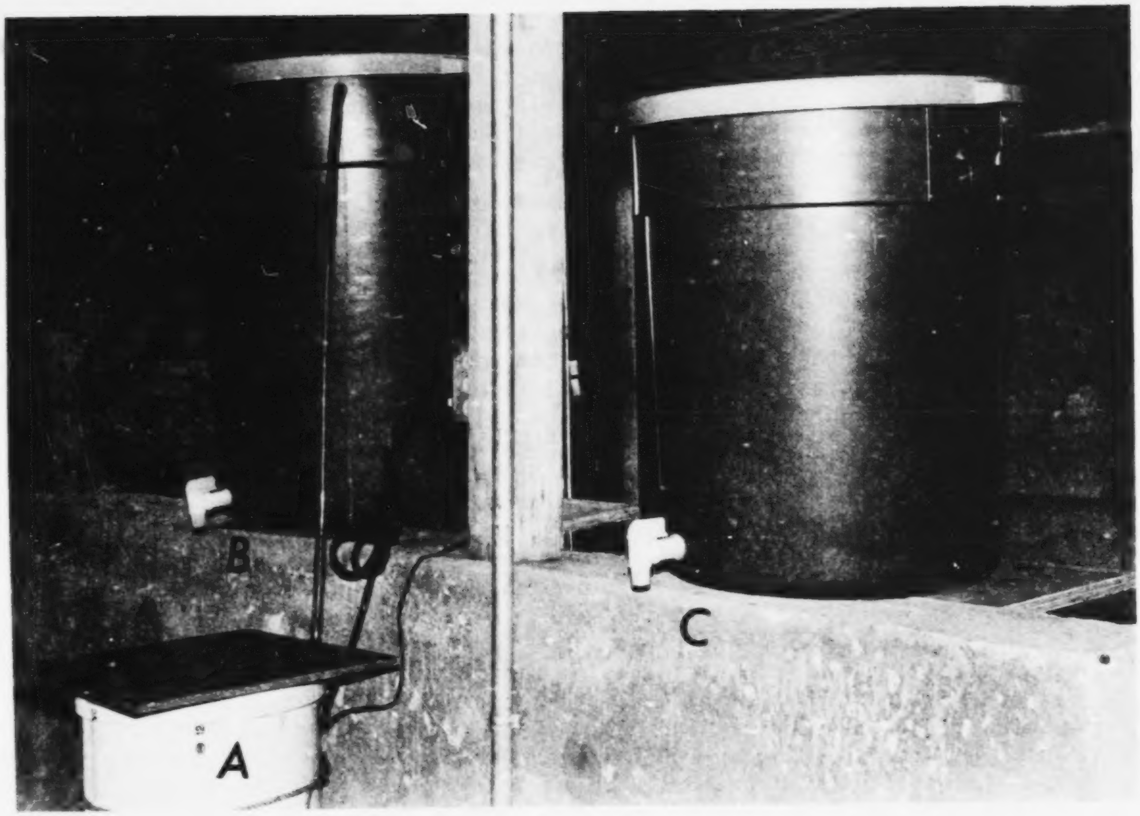
FIGURE 11. SEDIMENT DROP BOX USED TO COLLECT RUNOFF FROM DEFIANCE COUNTY WATERSHEDS.



A: Variable slit flume which diverts fraction of runoff into Coshocton wheel (B).

C: Sump collects discharge from Coshocton wheel; discharge is then pumped into sample container (Figure 13).

FIGURE 12. SYSTEM FOR MONITORING AND SAMPLING SURFACE RUNOFF AT DEFIANCE COUNTY WATERSHEDS.



A: Sump for collecting runoff. Contains sump pump which discharges into sample container (B).

C: Sample container for tile drainage.

FIGURE 13. SAMPLE CONTAINERS FOR RUNOFF AND TILE DRAINAGE AT DEFIANCE COUNTY WATERSHEDS.

The runoff was pumped into a 20-gallon plastic garbage can with a fitted lid (Figure 13). After each event, a subsample (usually 1 gallon) was taken from the container by a faucet at the bottom after thorough mixing. The remaining sample was discarded. The entire system was housed in a shed open only at the front, where the drop-box faced the field. The equipment was winterized by the use of heat lamps directed onto the Coshocton wheel and mounted in the sump and garbage can lids. Heating tape was used for all pipes. Even during the extremely low temperatures of 1977, the system never failed to operate during winter events.

Two subplots on the Hammersmith Roselms watershed (Figure 3) were established to measure runoff losses of sediment and nutrients from different slope positions on the landscape. One plot was situated on the top, more level portion of the watershed, while the other was placed on the steep, breaking part of the watershed as it sloped into the drainage channel. A steel V-flume was used to concentrate flow from the plot, which was bermed on the sides and rear to contain flow. The plots were 3 by 13.3m in size. A 2.5 cm-buried pipe with an inlet at the bottom and center of the flume carried runoff to the sampling shelter (Figure 3). A portion of the runoff was taken by a Coshocton wheel device (Figure 14), where it was collected and the volume measured manually. Samples were taken after each event for analysis.

Tile drainage. In all cases, a single tile line was monitored, except for the Blount site (402), where a small tile system was monitored by intercepting the main at the point where it discharged into the drainage ditch. The tile was usually at a depth of 3 feet, and a specially constructed fiberglas sump was set into the ground in the same sampling shelter used for surface runoff. The sump (Figure 15) intercepted the tile and collected all discharge. As in the case of surface runoff, a calibrated sump pump was used to pump the water out of the sump. A timer was used as before to measure pumping time, and the pump was activated at a given water level by electrode; it could also be activated manually. An orifice inserted into the discharge pipe from the pump delivered a sample of the water to a 20-gallon plastic garbage can, where it was subsampled as described previously. This sample was considered to be representative of the tile flow for a given time interval, since all of the flow was sampled. The amount of sample taken by the orifice was adjusted by a valve.

Sample Handling and Processing - All sites in Defiance County were serviced by technician every 48 hours or sooner if significant precipitation occurred. A 1-gallon subsample of the sample in the garbage can was taken after thorough mixing and the remainder discarded. Sumps were pumped dry manually after subsampling, time of pumping was recorded and rainfall at the site was measured from a manual rain gauge. Samples were stored in a refrigerator at 4° C at field headquarters until they could be transported to the laboratory at Columbus. Samples usually reached the laboratory within 7 days or less. Additional measurements taken in the field included depth of snow cover, depth to frozen soil and all pertinent details on field operations (times of planting, plowing, harvesting, rates of fertilization, etc.).

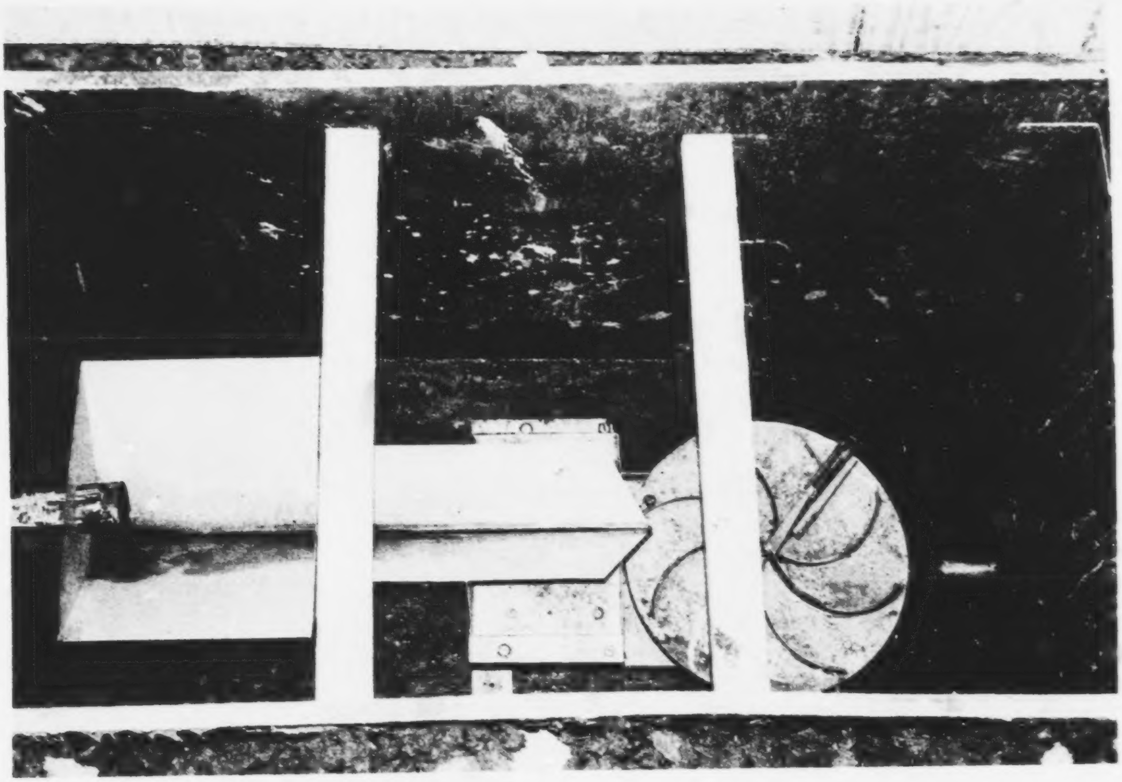
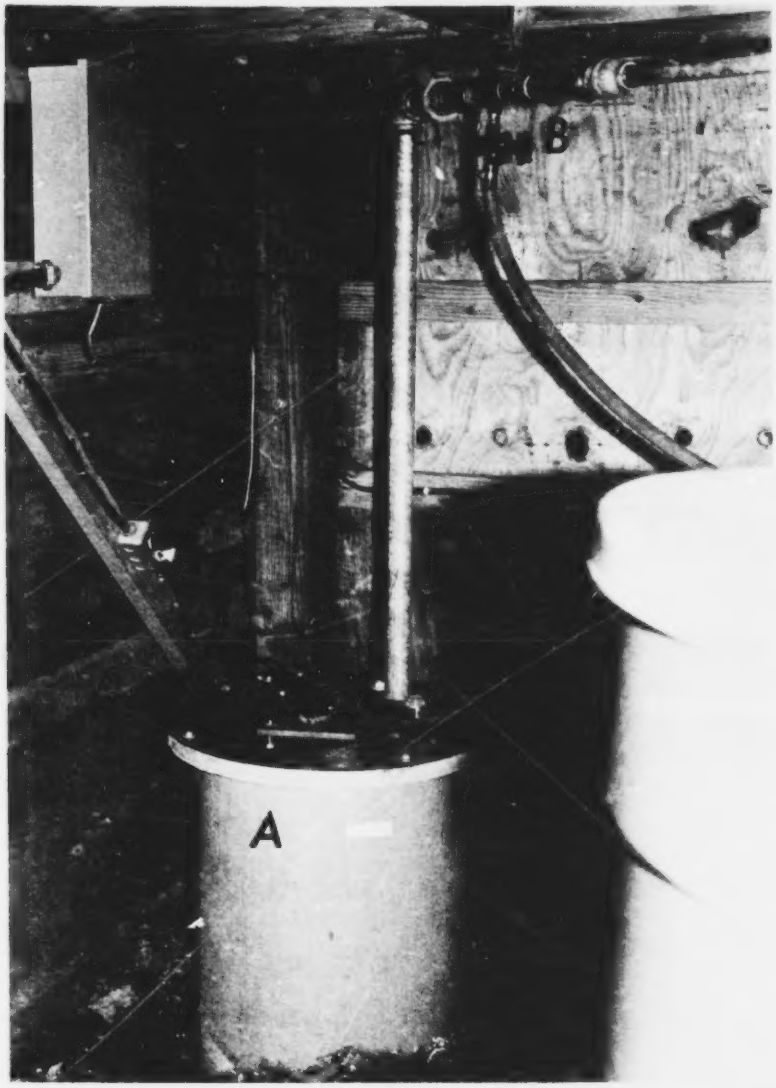


FIGURE 14. FLUME AND COSHOCTON WHEEL FOR SAMPLING COMPONENT PLOT RUNOFF AT HAMMERSMITH ROSELMS WATERSHED, DEFIANCE COUNTY, OHIO.



A: Fiberglas sump which intersects field tile. Contains submersible sump pump with flow-activating electrodes.

B: Sampling valve which diverts portion of sump pump discharge into sample container.

FIGURE 15. SYSTEM FOR MONITORING AND SAMPLING TILE FLOW.

Cropping practices: Agreements were made with all the farmer-operators to farm the sites to our specifications. All sites were fall-plowed with moldboard plow and planted to soybeans in the spring. Fall plowing is the most common cultural practice in Defiance County and many other counties in the Maumee River Basin (Table 10), and soybeans are a major crop in the region (Table 8). Therefore, the practices used in 1975-1977 were representative of those used in the Basin. Arrangements were also made to throw up berms around the defined plot area. A summary of practices is given in Table 2.

3.23 Surface Runoff and Tile Drainage Measurement-- Hoytville plots

In 1974, a research facility was constructed at the NW Branch, Ohio Agricultural Research and Development Center (OARDC), located at Hoytville in Wood County (Figure 1). to study the loss of soil and nutrients by runoff and tile drainage. Eight plots, each 30.5 m (100 ft) x 12.1 m (40 ft) were laid out, four in a block with a sampling house in the center (Figure 16). Each plot was trenched to a depth of four feet and heavy plastic sheeting was placed against the plot wall; the soil was then backfilled to hold the plastic in place. Earth berms (15-30 cm high) were raised on the sides of the plots and seeded with fescue. The back of the plots were left open to allow passage of equipment; a berm was then formed after each operation to enclose the plot. A concrete gutter was built on the other end of the plots with a 10 cm (4 inch) diameter drain to collect runoff. The drain was connected by 10 cm (4 inch) plastic pipe (placed at 90 cm depth) to the sampling house. A 10 cm (4 inch) perforated corrugated plastic tile was installed in the center of each plot at a depth of 90 cm. The tiles were also connected by 10 cm (4 inch) solid pipe to the sampling house. Additional field tile was placed outside the plot area to keep water other than that intercepted by the plots from entering the area. The hydraulic conductivity of the soil (Hoytville clay) was low enough to prevent any significant water movement between plots. The area between the plots and sampling house was seeded with fescue to prevent erosion.

The sampling procedure used was similar to that used to measure tile drainage on the Defiance County sites. Fiberglas sumps intercepted the flow from the surface runoff and tile drain lines. Sump pumps (Hydromatic submersible pump) and timers were used to measure flow as described previously, and water was sampled as before by placing an orificein the discharge line from the sump pump. The sampled water was collected in 1-gallon or 5-gallon plastic bottles housed in a refrigerated (4° C) compartment, so that the samples were refrigerated immediately. Samples were returned to the laboratory at Columbus within 1 week or less. Samplers were serviced daily and sumps were pumped dry between events. Precipitation records were kept by the personnel at the research station, which has a 20-year weather record.

The facility was completed early in 1975, and some flow and sediment monitoring was initiated in April 1975; water quality sampling was begun in May 1975. The previous fall, the plots were fall-plowed and left bare until planting in May 1975. The area had been in sod for at least 10 years prior to construction of the plots and had received no fertilizer during that period. In May 1975,

TABLE 2. SUMMARY OF CROP MANAGEMENT PRACTICES ON DEFIANCE COUNTY SITES

Hammersmith Roselms (10X)

	1975	1976	1977*
Tillage	Disked on May 25 Moldboard-plowed Nov. 7	Harrowed and disked May 12 Moldboard plowed Oct. 5	Disked May 24
Planting	Soybeans planted on May 25 in 30-inch rows	Soybeans planted May 12 in 30-inch rows	Soybeans planted in 9-inch rows May 24
Fertilization	None	200 lb/ac of 19-19-19 broadcast April 14	None
Pesticides	None	None	None
Harvest	Oct. 16 12-15 bu/ac	Oct. 2 15 bu/ac	-- --

Crites Roselms (20X)

	1975	1976	1977
Tillage	Disked May 27; partially washed out on May 29, redisked June 10, chisel plowed Oct. 15	Disked April 12	--
Planting	May 27; replanted June 10, soybeans drilled in 9 inch rows	Soybeans drilled May 22, no germination; replanted June 8 in 30-inch rows	--
Fertilization	None	None	--
Pesticides	1 lb/ac Lorox; 1 qt/ac Lasso May 27	1 lb/ac Lorox; 2 qt/ac Lasso; at planting	--
Harvest	Oct. 5; 30 bu/ac	Oct. 4; 20 bu/ac	--

TABLE 2. (CONTINUED)

Rohrs Lenawee (30X)

	1975	1976	1977
Tillage	Disked May 25	Disked May 13	--
	Fall-plowed Oct. 16	Fall-plowed Oct. 23	
Planting	Soybeans planted in 30-inch rows May 25	Soybeans planted in 30-inch rows May 20	--
Fertilizer	130 lb/ac 0-23-30 May 25 applied in row	130 lb/ac 0-23-30 banded May 20	--
Pesticides	10 lb/ac Lasso-banded at planting	10 lb/ac Lasso-banded at planting	--
Harvest	Oct. 5; 45 bu/ac	Oct. 8; 40-45 bu/ac	--

Heisler Blount (40X)

	1975	1976	1977
Tillage	Disked May 24	Disked May 13	--
	Fall-plowed Oct. 15	Oct. 12 chisel-plowed	
Planting	Soybeans planted in 30-inch rows May 24	Soybeans drilled May 13	--
Fertilization	None	100 lb/ac 4-10-10 liquid fertilizer May 13	--
Pesticides	1 lb/ac Lorox, 2 qt/ac Lasso May 24	1 lb/ac Lorox, 2 qt/ac Lasso May 13	--
Harvest	Oct. 5; 30 bu/ac	Oct. 4; 30 bu/ac	--

TABLE 2. (CONTINUED)

Speiser Paulding (50X)

	1975	1976	1977
Tillage	**Disked** May 16 chisel plowed Oct. 23	April 26 **disked** Oct. 23 chisel plowed	--
Planting	Soybeans planted May 20 in 30-inch rows	Soybeans planted May 22 in 30-inch rows	--
Fertilization	None	None	--
Pesticides	8 lb/ac granular Amiben at planting	8 lb/ac granular Amiben at planting	--

* Monitoring of all sites was discontinued in May, 1977, the project termination date.

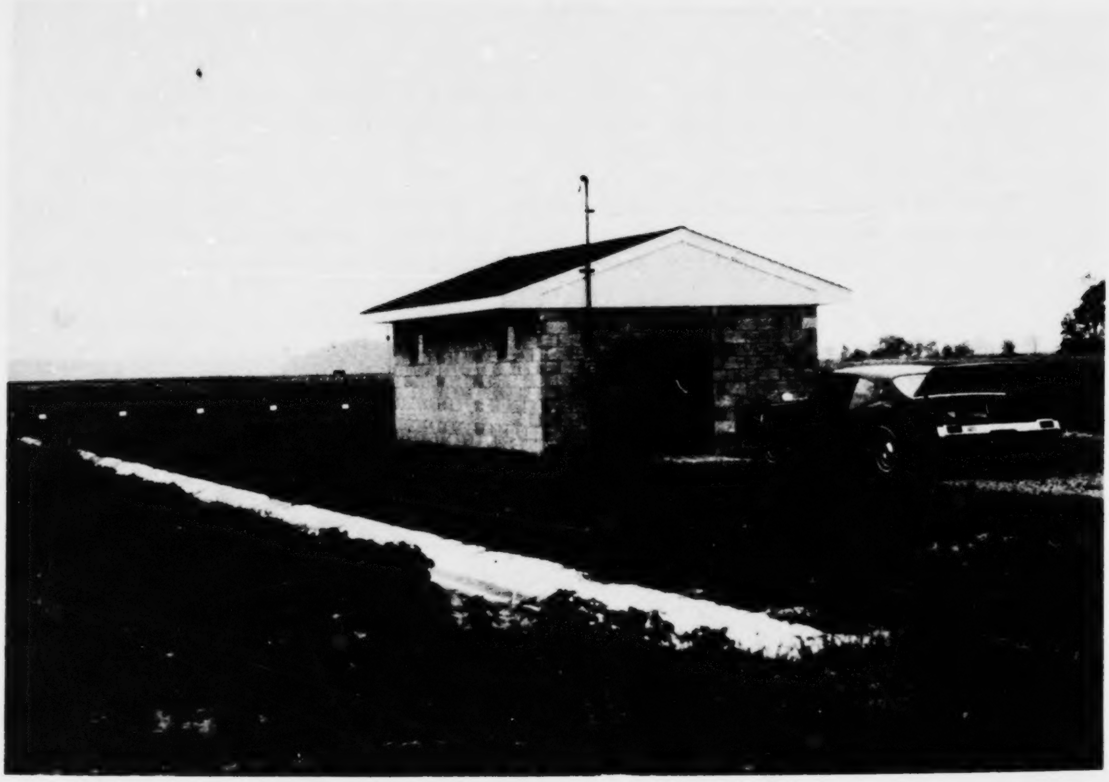


FIGURE 16. RUNOFF AND TILE DRAINAGE PLOTS AT OARDC RESEARCH STATION, HOYTVILLE, OHIO.

soybeans were planted and the monitoring period, May-November 1975, was used to measure the variability between plots. Table 3 summarizes all crop management activity in 1975-1977. In November 1975 a tillage variable was made on the plots. Four tillage treatments were selected:

1. Moldboard-plow in the fall
2. Chisel-plow in the fall
3. Strip-rototill in the fall
4. No till

These four treatments were assigned at random within each of the two blocks, the blocks serving as replicates. In the strip-rototill tillage treatment, a rototiller was used to cultivate a strip of soil approximately 15 cm wide and 15 cm deep, the strips spaced at 30-inch (76 cm) intervals, leaving crop residue between the strips. All tillage treatments were made parallel to the long axis, as well as planting. In fall 1976, a single disking was substituted for the rototill treatment.

The effectiveness of tillage for erosion control is a function of the amount of the soil surface that is kept covered by crop residue. In terms of percent residue cover, the treatments might be ranked:

no-till > strip-rototill > chisel-plow > moldboard-plow

It should be recognized that soybeans provide less residue cover than corn. On Morley soil, no-till corn gave 53-78% cover while no-till soybeans gave only 26%; chisel-plow corn was 29-57% as compared to 12% for soybeans, and moldboard-plow gave 4% with corn and only 1% with soybeans (Mannering and Johnson, 1975).

As can be seen from Table 3, no nitrogen fertilizer was added to the plots.

3.24 Analysis of watershed and plot water samples

The water samples received from the various sites were processed and analyzed for a number of parameters; some parameters were measured on all samples, some were measured on periodic samples, while others were measured on all samples for a period of time and then discontinued.

As soon as samples were received in the laboratory, the 1-gallon polyethylene bottles were shaken thoroughly and a 250 ml sample was placed in another bottle and refrigerated (Figure 17). If the sample contained significant amount of sediment, the remainder of the sample was treated with 100 ml of 1N $MgCl_2$ per gallon to flocculate the sediment. The sediment was allowed to settle, the supernatant discarded, and the sediment was freeze-dried and saved for further analysis. A 100 ml sample of the unfiltered sample was filtered through a preweighed 1.0 um Nucleopore membrane filter. The sediment and filter were oven-dried, reweighed, and sediment concentration calculated. The filtered solution was refrigerated until further analysis. Tests showed that a 1.0 um filter was effective in retaining fine clay. The filtered sample was routinely analyzed for: pH, electrical conductivity (E. C.), Ca, Mg, K, Na, CO_3, HCO_3, $NO_3 + NO_2$, NH_3, and filtered reactive-P. Analysis for pH, E. C., CO_3, HCO_3, Ca, Mg, K, and Na was discontinued after one year because of lack of variability of the data and the secondary importance of those parameters.

TABLE 3. SUMMARY OF CROP MANAGEMENT PRACTICES ON THE HOYTVILLE PLOTS (1974-1977).

1974

1. Tillage - plots were fall-moldboard plowed and leveled in August

1975

1. Tillage - seedbed was prepared by cultivating on May 15
2. Planting - soybean variety "Beeson" was planted on May 15, using a 2-row planter and 30-inch spacing
3. Pesticide - 0.5 lb/ac Sencor, 2.25 lb/ac Lasso, May 16
4. Harvest - beans were combined on October 7, using a research small plot harvester. Yield was measured (59.4 bu/ac)
5. Tillage - Plots were tilled according to treatment on October 30
6. Fertilization - 34 kg/ha P and 100 kg/ha K were broadcast on the plots just prior to tillage

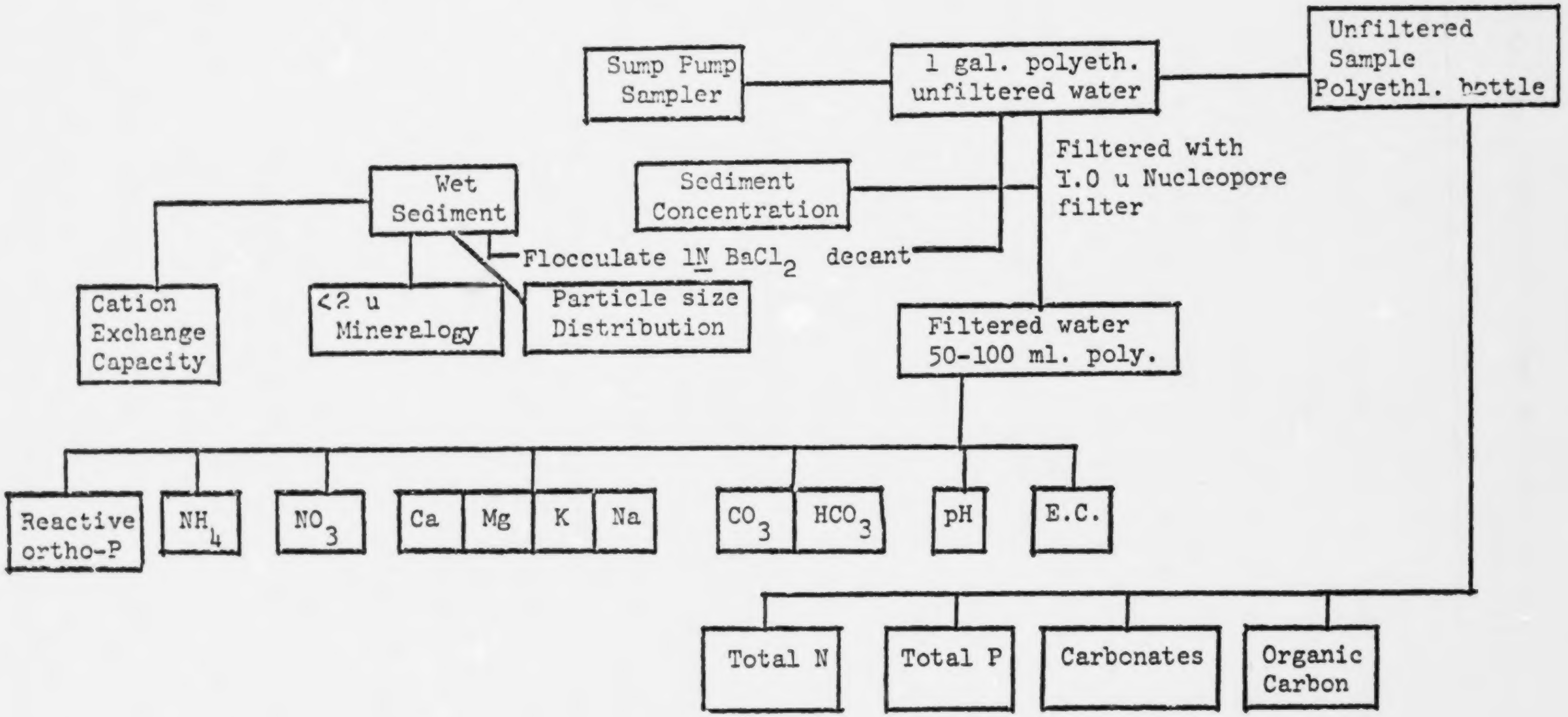
1976

1. Tillage - seedbed was prepared by field cultivation on May 5 (except no-till plots, which were untouched)
2. Fertilization - row fertilizer 7 kg/ha N, 12 kg/ha P, 22 kg/ha K; May 5
3. Planting - Planted "Williams" variety soybeans on May 5; 30-inch rows
4. Pesticide - 0.5 lb/ac Sencor, 2 qts/ac Lasso, 1 lb/ac Roundup
5. Harvest - October 5 (41.1 bu/ac)
6. Fertilizer - 34 kg/ha P and 83 kg/ha K was broadcast before tillage; October 26
7. Tillage - November 5

1977

1. Tillage - All plots except no-till were field-cultivated on May 13
2. Fertilization - 7 kg/ha N, 12 kg/ha P and 22 kg/ha K was applied in row at planting; May 13
3. Planting - "Beeson" variety soybeans in 30-inch rows; May 13
4. Pesticide - 0.5 lb/ac Sencor, 2 qts/ac Lasso, 1 lb/ac Roundup
5. Harvest - September 29 (48.3 bu/ac)

FIGURE 17. FLOWSHEET: RUNOFF AND TILE DRAINAGE SAMPLES.


Sump Pump Sampler
1 gal. polyeth. unfiltered water
Unfiltered Sample Polyethl. bottle
Filtered with 1.0 u Nucleopore filter
Sediment Concentration
Wet Sediment
Flocculate 1N BaCl$_2$ decant
Cation Exchange Capacity
<2 u Mineralogy
Particle size Distribution
Filtered water 50-100 ml. poly.
Reactive ortho-P
NH$_4$
NO$_3$
Ca
Mg
K
Na
CO$_3$
HCO$_3$
pH
E.C.
Total N
Total P
Carbonates
Organic Carbon

The unfiltered sample was analyzed for: total P, total N, and carbonates; organic carbon was analyzed for a few samples.

Some samples were occassionally analyzed for other parameters and these will be discussed later for those specific studies. All procedures used are given in Appendix.

3.3 Calculation of Loadings

3.31 Major and Minor Sub-basins

Loadings for the Maumee and Portage River basins and the two Black Creek sub-basins were estimated by the use of the Beale ratio estimator and the algorithm for its solution provided in the Task C Handbook (IJC, 1976) and other communications (Clark, 1977). The theory behind and the utility of the estimator has been discussed by several other investigators (Konrad et al, 1977) (Sonzongni et al, 1978) (Ostry et al, 1978), and will not be discussed further here beyond justification for the method of stratification used.

Sampling methods in the Maumee and Portage River studies meet the requirements of randomness in that samples have been taken from the two rivers every six hours, except for equipment downtime, for over three years. Of these samples at least one has been analyzed every day. In the event of a rise in the hydrograph due to the occurrence of storm runoff, all four of the samples taken during the course of a day and for the duration of the runoff event are analyzed. Sampling frequency is not otherwise altered during storms.

In the Black Creek studies the sampling is non-random. Samples there were taken on a one-sample-per-week basis except in the case of a storm of more than 2.5 cm of surface runoff to start stage-actuated automatic sampler with collection of samples at 30-minute intervals. A third flow regime is designated for all flows between a defined base-flow (flow < 0.0221 m^3/sec at site 2 or < 0.0107 m^3/sec at site 6) and the large-event flows (flow > 0.218 m /sec at site 2 and site 6). No samples are specifically collected in this flow interval unless they were by chance collected during the once-weekly grab-sampling program.

Since it was desirable to determine loadings on a monthly basis for the purpose of examining variations in sediment and nutrient delivery through the year, twelve strata across one year of data are immediately created. For the Maumee and Portage three additional strata are defined within each month:

1) baseflow - level of flow within each month below in which hour-to-hour variations in flow appear to be random;

2) rising hydrograph - the upside of the hydrograph; and

3) falling hydrograph - the downside and return to baseflow or new storm.

At the Black Creek sites the same strata are defined and a fourth for all small-event flows in the interval defined above is used. The only other difference in definition of strata for Black Creek is that the baseflow value is uniform throughout the year, whereas for the major basins it is defined differently for each month.

Thereafter, calculation of loadings and the error term proceed as described in Sonzogni et al (1978).

Table 4 summarizes the observations used in the loading calculations.

TABLE 4. NUMBERS OF OBSERVATIONS IN STUDY WATERSHEDS

		Dissolved Inorganic Phosphorus	Total Phosphorus	Suspended Sediment	Nitrate+ Nitrite-N	Ammonia-N
Maumee	1975	477	468	459	465	473
	1976	601	634	619	623	590
	1977	409	421	420	396	413
Portage	1975	487	427	465	502	460
	1976	569	568	568	573	575
	1977	368	387	388	368	366
Black Creek Site 2	1975	641	641	640	641	641
	1976	397	397	397	397	397
Black Creek Site 6	1975	455	455	455	454	452
	1976	409	409	409	409	409

3.32 Experimental Plots

Loadings from the thirteen experimental plots were calculated strictly by the multiplication of a "flow-weighted mean" concentration by the total flow for each storm event for surface runoff and total periodic flow from tiles. These plots are very small (0.04-3.2 ha) and surface flow is ephemeral, occurring only for the duration of storm events. Flow from the tiles is more sustained but still intermittent. The total flow from each event is continuously sampled and composited by a flow-proportional pump. The concentration of the composite sample is considered to represent the flow-weighted mean concentration of the runoff occurring during a single storm event. Loadings from these plots are presented in tabular form for each month of the two-year sampling period for comparison with the monthly loadings of the other basins.

3.33 Other Loading Estimates

All calculations of loadings, including total loads and unit area yields, are based on the mean daily load determined for each month for the major and sub-basins and on the total monthly load calculated for the experimental plots. The standard error of the mean daily loading estimates is presented in the tables with those estimates. There is no error term presented for the experimental plot-loading estimates.

3.34 Application of Experimental Plot Data to Major Basin Data

The experimental plot watersheds were chosen as representative of major soil groups found in the Maumee Basin. In order to compare the yields from these plots to yields from the other watersheds in the study, it was necessary to derive some mean value of the yields from the plots. A simple arithmetic mean would of course weight soils that occur less frequently too much and soils that are abundant too lightly. We felt that an area-weighted mean could be used to effect the extrapolation of the experimental plot data for the comparison.

Obviously, the six soils of the plots do not perfectly represent all the soils found in the Maumee River Basin, but they do represent all major physiographic types found and a full range of slope categories, drainage types and soil textures. The only purpose of this reclassification is to provide figures for the extrapolation. No further use should or will be made of these figures. The soil series and their area weights are:

	Area Weight
Roselms (3-15% slope)	0.05
Roselms (3-5% slope)	0.23
Lenawee	0.15
Blount	0.28
Paulding	0.08
Hoytville	0.21

4. RESULTS

4.1 Description of the Basin

4.11 Topography and drainage

The low relief topography of the Basin is the result of glacial action and subsequent stream erosion. Elevations around the perimeter of the Basin are about 305 m (1000 ft), while the central lowland, the Maumee Lake Plain averages about 183 m (600 ft). The drainage patterns of the Maumee River and its tributaries are governed by the various moraines which are found in the Basin (Figures 18 and 19). The St. Marys River, flowing northwest from Shelby County, Ohio and the St. Joseph flowing southwest from Hillsdale County, Michigan are examples of moraine-controlled drainage. They converge at Fort Wayne and flow northeast as the Maumee because of the dam-like effects of the Ft. Wayne and Wabash moraines. Other major tributaries to the Maumee are the Auglaize, Blanchard, and Tiffin Rivers. The low relief, and fine texture of the Basin soils, result in overall poor drainage for the soils in the Basin. Northwest Ohio, formerly known as the Black Swamp, was one of the last areas in Ohio to be settled with widespread agriculture only in the last 100 years or less. Drainage improvements are required on greater than 80% of all soils in the Basin, with the better drained soils occuring in the glacial till plain region on the perimeter of the Basin where there is more relief. Tile drainage is the most common method of drainage improvement, although surface channel drains are used as well, especially on the very heavy-textured Lake Plain soils, such as Paulding, whose low hydraulic conductivities make them unresponsive to tile drainage. The extensive and growing network of tile and surface drainage in the Maumee River Basin is served by a vast network of drainage ditches and man-made or improved channels. The low relief of the Basin results in a continuous problem of drainage outlet;tile outlets are frequently inundated during the spring rains, and the main channels often flood their banks. Water will stand on the field for days until the major channels drain sufficiently to permit upstream drainage. The Basin, then, responds slowly to rainfall as evidenced by the broad hydrographs recorded downstream. This optimizes the opportunities for sediment deposition in the ditches and channels, a factor which is compensated for by the high clay content of the soils in the Basin. The continuous ditch clean out programs in the Basin are testimony to the process of sediment deposition, although some sediment is contributed from stream bank erosion.

The Maumee River and its tributaries are intercepted by several dams, notably the Cedarville Reservoir on the St. Joseph, the Power Dam on the Auglaize, and Independence Dam on the Maumee. These will detain some sediment, but detention of the fine suspended sediment is probably minimal.

4.12 Geology

The exposed bedrock in the Basin is chiefly Silurian limestone and dolomite; Devonian shale crops out north of the Maumee River, and some Mississippean sandstone is exposed along the northern edge of the Basin. Glacial drift of varying thickness covers the bedrock from Kansan, Illinoian, and Wisconsian periods. Prior to the Wisconsian glaciation, the Teays-Stage drainage constituted the only extensive network of ancient valleys in the area. Surficial deposits are either morainal till or lake clays and these regions (Figure18) are designated till plain or lake plain. In addition, a number of beach ridges associated

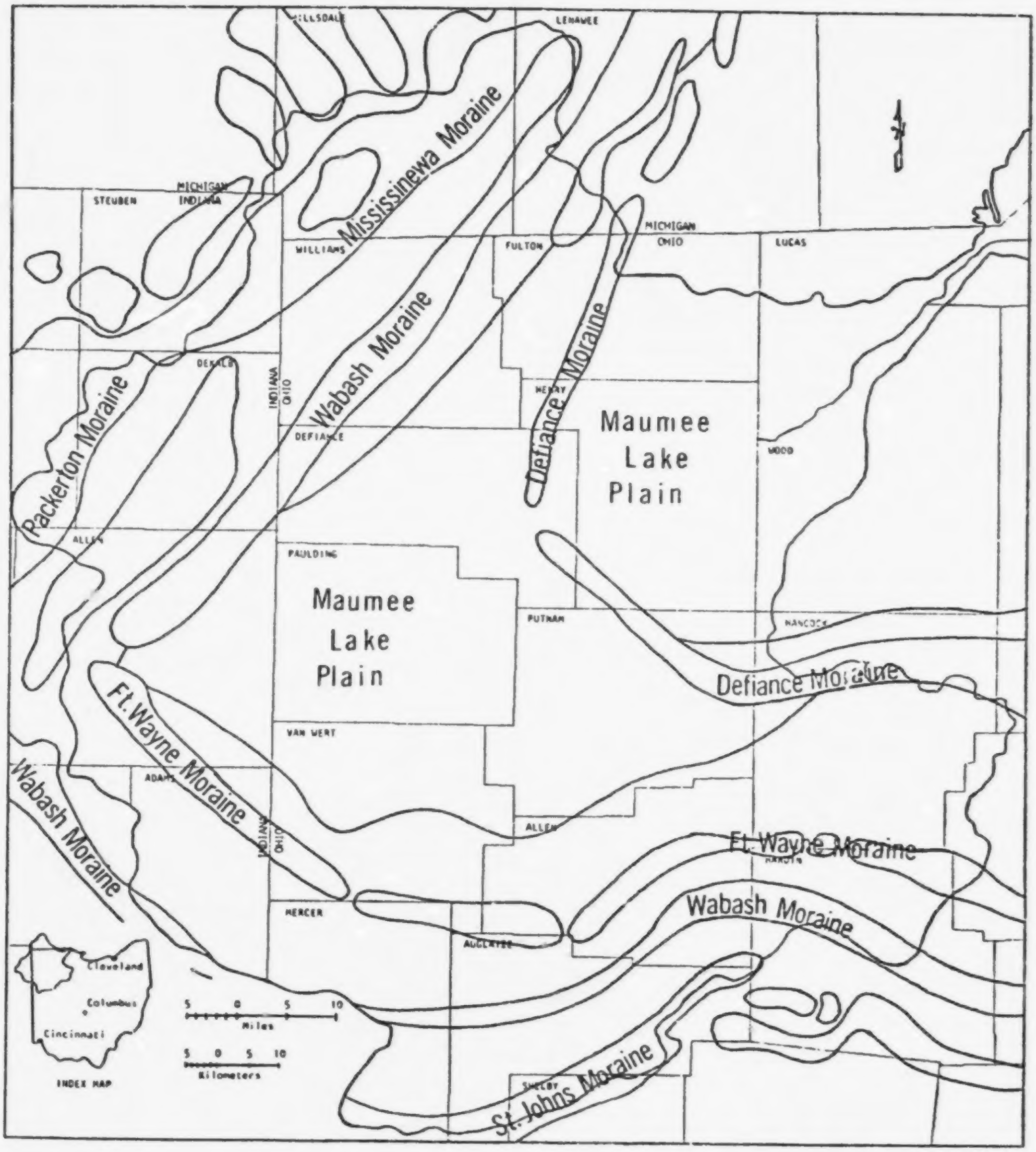

HILLSDALE
LENAWEE
Mississinewa Moraine
MICHIGAN
INDIANA
STEUBEN
WILLIAMS
FULTON
MICHIGAN
OHIO
LUCAS
Wabash Moraine
Defiance Moraine
Packerton Moraine
DEKALB
INDIANA
OHIO
HENRY
DEFIANCE
Maumee Lake Plain
WOOD
ALLEN
PAULDING
Maumee Lake Plain
PUTNAM
HANCOCK
Defiance Moraine
Ft. Wayne Moraine
VAN WERT
ADAMS
Wabash Moraine
INDIANA
OHIO
ALLEN
Ft. Wayne Moraine
HARDIN
Wabash Moraine
MERCER
AUGLAIZE
Cleveland
Columbus
Cincinnati
INDEX MAP
5 0 5 10
Miles
5 0 5 10
Kilometers
SHELBY
St. Johns Moraine
N

FIGURE 18. GLACIAL DEPOSITS OF THE MAUMEE BASIN (MODIFIED FROM PETTYJOHN, HAYES AND SCHULTZ, 1974.)

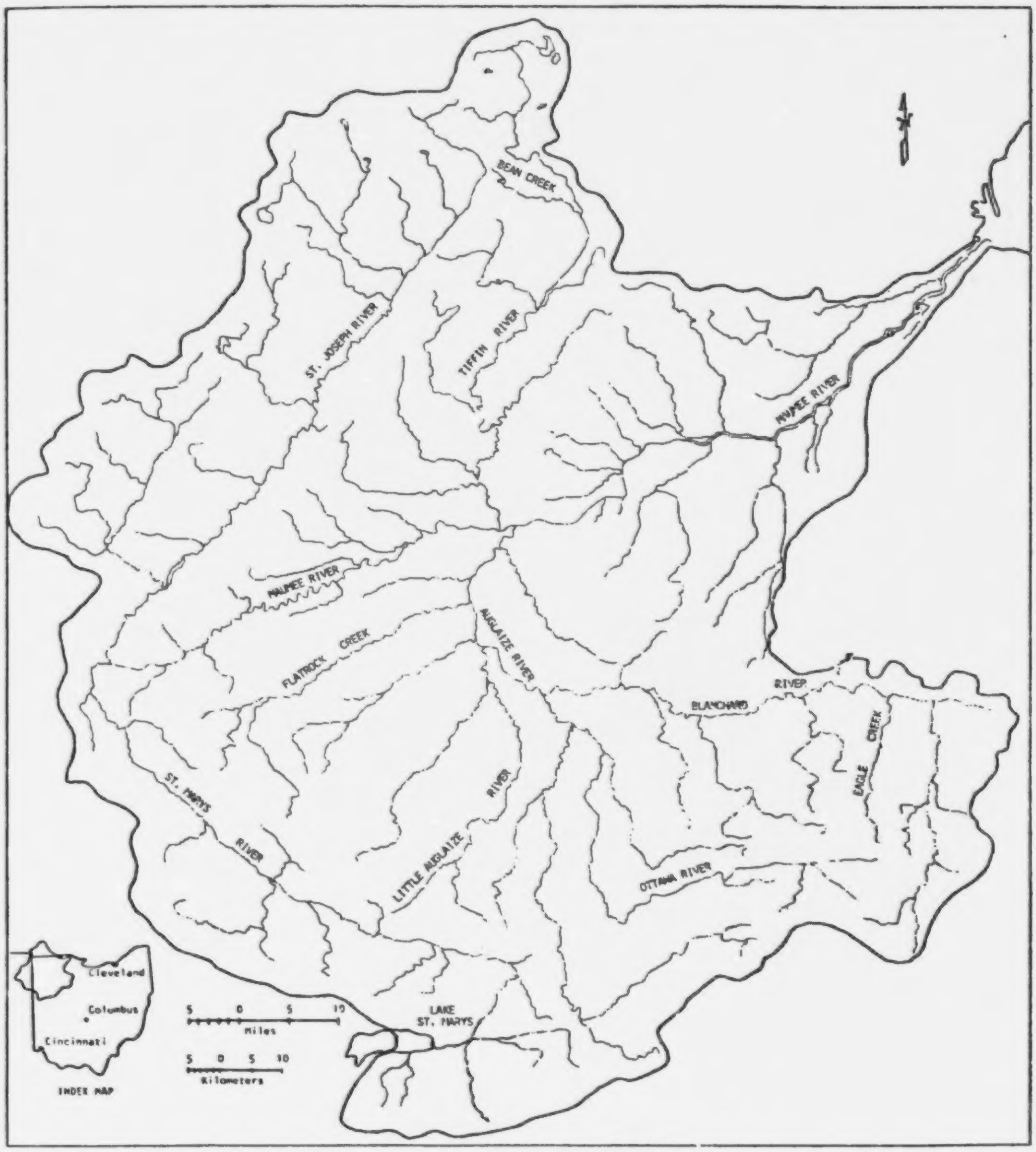

BEAN CREEK
ST. JOSEPH RIVER
TIFFIN RIVER
MAUMEE RIVER
MAUMEE RIVER
FLATROCK CREEK
AUGLAIZE RIVER
BLANCHARD RIVER
EAGLE CREEK
ST. MARYS RIVER
LITTLE AUGLAIZE RIVER
OTTAWA RIVER
LAKE ST. MARYS
Cleveland
Columbus
Cincinnati
INDEX MAP
5 0 5 10
Miles
5 0 5 10
Kilometers

FIGURE 19. RIVERS OF THE MAUMEE BASIN

with the Wisconsian age Lake Maumee are found in the Basin. The Maumee River Basin can be visualized as a shallow pond with a spout, the moraines (Figure 18) the rim of the pan, the lake plain, the bottom, and the Maumee River entering Lake Erie the spout. The soils of the Basin, their drainage, erosion hazard, etc. are determined by these glacial features. A more complete description of the Maumee Basin glacial geology is given by Forsyth (1965, 1966), Golthwait, White and Forsyth (1961), Herdendorf (1970), Hough (1958), Indiana Geological Survey (1956), Stout (1943), Wayne (1958), Wayne and Zumberge (1965) and Zumberge (1960).

4.13 Hydrology

The Maumee River Basin is in the north temperate zone; its climate is humid, with warm summers and mildly cold winters. Mean annual temperature is 11°C (51°F) for the period 1931-1960. Mean monthly maximum temperature approaches 24°C (75°F) in July with mean monthly minimum temperature of -3°C (27°F) in January. The frost-free season averages about 170 days (Ohio Water Commission, 1967).

The mean annual precipitation in the Maumee River Basin is 864 mm (34 inches), based on U.S. Weather Bureau records (1931-1960). The distribution within the Basin is given in Figure 20. The lowest monthly rainfall between 1921 and 1965 was 0.5 mm (0.02 inches) in October, 1963 at Lima; the highest, also at Lima was 232 mm (9.14 inches) in May, 1954. At Hoytville in 1975, 231.6 mm (9.12 inches) was received in August. Water loss in the Basin, mean rainfall minus mean streamflow averages 610 mm (24 inches).

The streams in the Maumee have relatively low gradients and long lengths. The Maumee itself has a gradient of 24.6 cm/km (1.3 feet/mile) for 241.5 km (150 miles). The St. Joseph, St. Marys, Auglaize, and Blanchard Rivers, all about 161 km (100 miles), have gradients of 58.7, 47.3, 60.6, and 17.0 cm/km (3.1, 2.5, 3.2, and 0.9 feet/mile), respectively (Ohio Division of Water, 1960). The Tiffin River, 96.6 km long (60 miles), has a gradient of only 22.7 cm/km (1.2 feet/mile) (Pettyjohn, Hayes and Shultz, 1974).

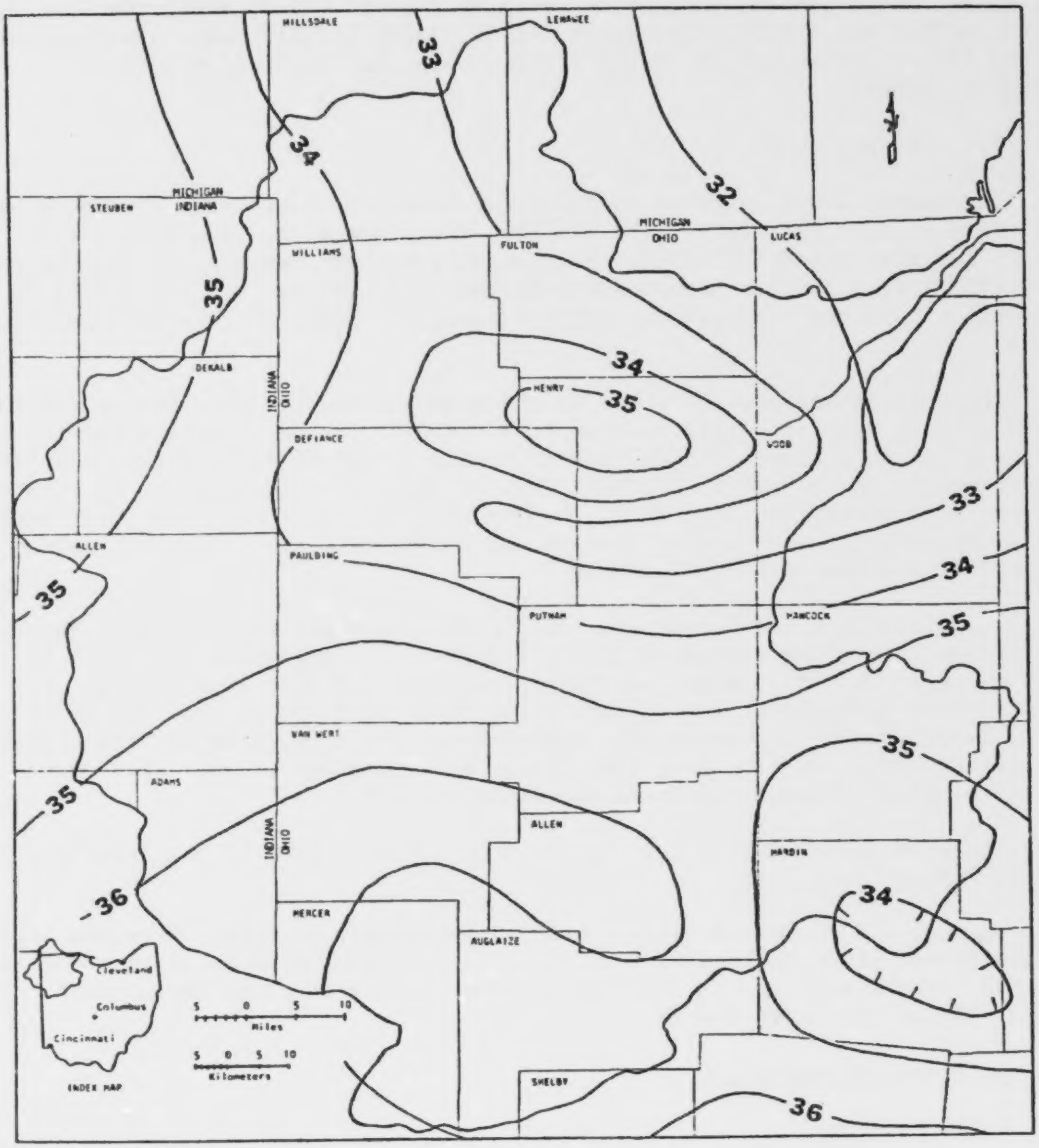
The mean annual stream flow in the Maumee River Basin is approximately 203-275 mm (8-11 inches).

Naymik (1977) has recently completed an extensive survey of ground water in the Maumee River Basin. Percent of total discharge attributed to ground water in 1973 at Waterville, the last downstream gauging station, accounted for 32-39% of the total discharge.

4.2 Land use and practices

4.21 Land Use

The Maumee River Basin drains 17,058 km^2 (6,586 mi^2) into the Western Basin of Lake Erie at Toledo. It has 73.7, 19.1, and 7.2% of its acreage in Ohio, Indiana, and Michigan, respectively. Seventeen Ohio counties, four in Indiana and two in Michigan are wholy or partially in the Basin. Figure 21 identifies the communities in the Basin, 19 of which have populations greater than 5000. Of the approximately 1.4 million population, about 75% is centered in the Toledo (580,000), Fort Wayne (281,000), Lima (171,500) and Findlay (30,000) areas.


HILLSDALE
LENAWEE
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33
34
32
MICHIGAN
INDIANA
STEUBEN
WILLIAMS
FULTON
MICHIGAN
OHIO
LUCAS
35
DEKALB
INDIANA
OHIO
34
HENRY
35
DEFIANCE
WOOD
33
ALLEN
PAULDING
34
35
PUTNAM
HANCOCK
35
VAN WERT
35
35
ADAMS
ALLEN
INDIANA
OHIO
HARDIN
36
34
MERCER
AUGLAIZE
Cleveland
Columbus
Cincinnati
5 0 5 10
Miles
5 0 5 10
Kilometers
INDEX MAP
SHELBY
36

FIGURE 20. AVERAGE ANNUAL PRECIPITATION, IN INCHES, FOR THE PERIOD 1931-1960 (MODIFIED FROM OHIO WATER PLAN INVENTORY, 1962).

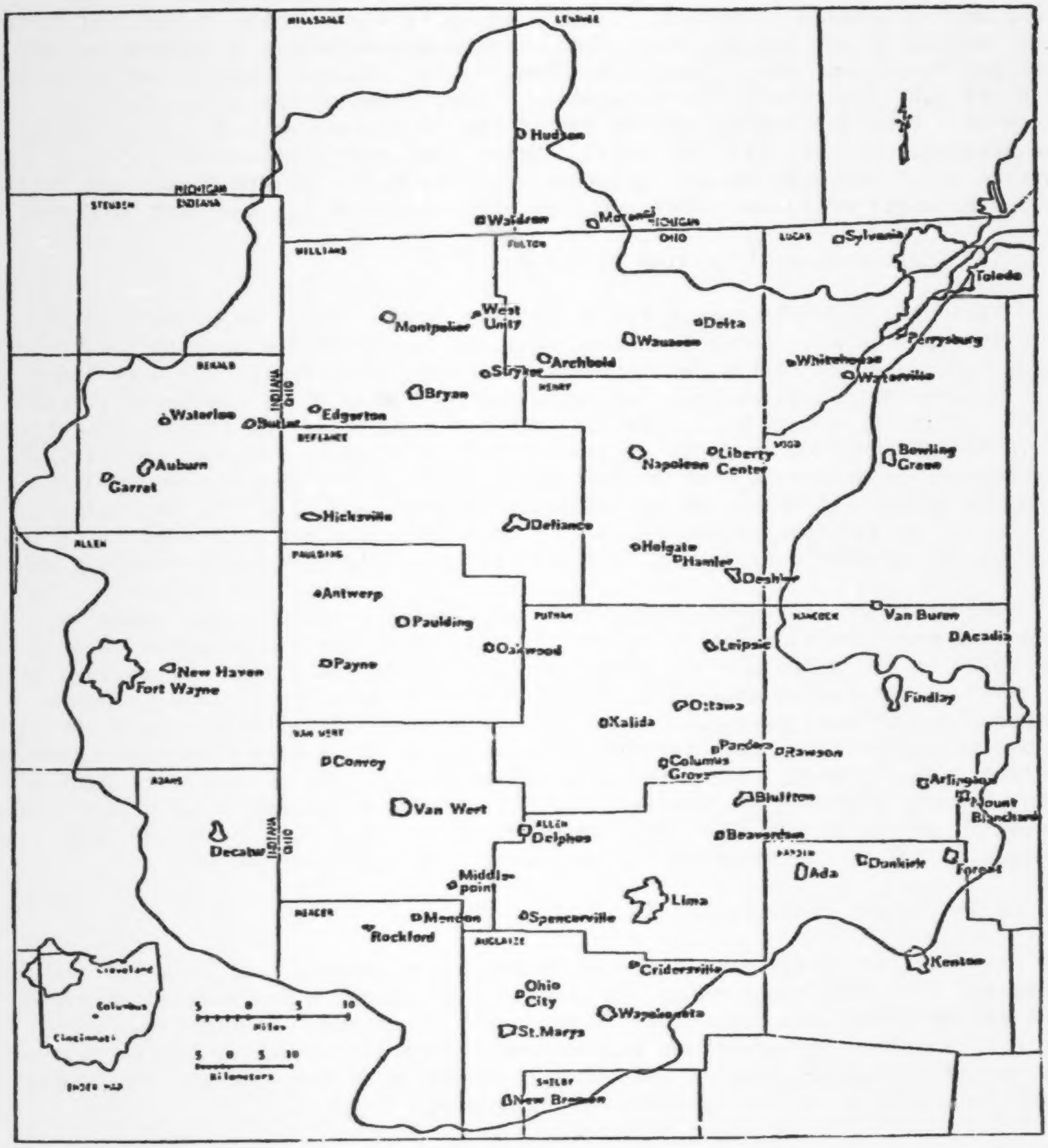
HILLSDALE
LENAWEE
Hudson
MICHIGAN
INDIANA
STEUBEN
Waldron
Morenci
MICHIGAN
OHIO
LUCAS
Sylvania
Toledo
WILLIAMS
FULTON
Montpelier
West Unity
Delta
Wauseon
Perrysburg
Archbold
Whitehouse
Stryker
Waterville
HENRY
DEKALB
INDIANA
OHIO
Bryan
Edgerton
Waterloo
Butler
DEFIANCE
Napoleon
Liberty Center
WOOD
Bowling Green
Auburn
Garrett
Hicksville
Defiance
ALLEN
Holgate
Hamler
Deshler
PAULDING
Antwerp
Paulding
PUTNAM
HANCOCK
Van Buren
Acadia
Oakwood
Leipsic
New Haven
Fort Wayne
Payne
Findlay
Ottawa
Kalida
Pandora
Rawson
VAN WERT
Convoy
Columbus Grove
Arlington
Van Wert
Bluffton
Mount Blanchard
ADAMS
Decatur
INDIANA
OHIO
ALLEN
Delphos
Beaverdam
HARDIN
Ada
Dunkirk
Forest
Middle-point
Lima
MERCER
Mendon
Spencerville
Rockford
AUGLAIZE
Kenton
Cridersville
Cleveland
Columbus
Cincinnati
INDEX MAP
5 0 5 10
Miles
5 0 5 10
Kilometers
Ohio City
Wapakoneta
St. Marys
SHELBY
New Bremen

FIGURE 21. THE MAUMEE RIVER BASIN METROPOLITAN AREAS.

Table 5 gives the total and urban populations for the counties that are wholely in the Basin or have a large percentage of their area in the Basin. The area of each county is also given. This data is taken from the PLUARG Task B report for planning subarea (PSA) 4.2. Table 6 gives land use in the Maumee and Portage River Basins by sub-basins. This data is reproduced here with permission of Resource Management Associates, West Chester, Pa. It was prepared under contract with the Lake Erie Wastewater Management Study, Corps of Engineers, Buffalo District. Cropland represented 65-80% of the total area with deciduous forest the next largest land use with 5-13%. Urban land uses represented a small portion of the various basins, reemphasizing the fact that the Maumee and Portage Basins have primarily intensive row crop agriculture as its dominant land use.

4.22 Agricultural Practices in the Basin

Agriculture in the Maumee River Basin is dominated by the production of only 5 crops: corn, soybeans, wheat, oats,and hay. Other crops, including sugar beets and vegetables for processing and the fresh market are very important economically, but account for less than 5% (Table 7) of the total acreage harvested in any county in the Basin. Table 8 summarizes the totals of acreages harvested of the five crops in each county of the Basin. For most counties the figures represent the mean of production in 1975 and 76. Data were obtained from the 1976 publications of the Michigan, Indiana and Ohio Crop Reporting Services. In addition to the production data these reports were used to derive crop yield, tillage practice,and dates of tillage, planting,and harvesting data.

The soils of the Maumee River Basin are highly productive for these crops and precipitation (34.06 in, 86.5 cm) is ample for nonirrigated agriculture. The soils of the Basin are all associated with a glacial origin and include lake deposits, till plain, outwash plain and scattered deposits of sand in beach ridges, ancient sand bars,and ground and end moraines. Particle-size distributions are dominated by the clay fraction, and most soils have high organic-matter content. The greatest single agricultural problem is the provision of drainage. When adequate drainage is provided, usually through subsurface tile drains, corn yields in excess of 140 bu/ac are not uncommon. It has been estimated that upwards of 50% of the cropland in the Maumee Basin is underdrained.

4.23 County Crop Rotations

In order to derive C, tillage or conservation practice, factors for the Universal Soil Loss Equation, it was necessary to quantify the acreage of cropland in the Basin in a variety of logical crop rotations. Observations of typical rotations and practices suggest six assumptions which enable the use of the county production data to calculate the acreage of cropland in each county which is typically in one of 7 rotation patterns.

The assumptions are:

1. The effect of soil type and physiography on crop rotation is sufficiently accounted for by using county crop-reporting statistics.

2. All wheat is in a corn-soybean-wheat rotation.

    A. 50% of acres of hay harvested modifies this rotation to: C SG W M
    B. 100% of all oats are planted in the spring following corn.

TABLE 5. POPULATION DATA BY COUNTY (PLUARG TASK B)

	TOTAL POPULATION				Number Urban 1970	Percent Urban 1970	Land Area mi² 1970	Area in Basin	% in Basin
	1940	1950	1960	1970					
PLANNING SUBAREA 4.2									
Indiana									
Adams	21,254	22,393	24,643	26,871	11,433	42.5	345		
Allen	155,084	183,722	232,722	280,455	225,184	80.3	671		
De Kalb	24,756	26,023	28,271	30,837	12,052	39.1	366		
Ohio									
Allen	73,303	88,183	103,691	111,144	76,428	68.8	410	410	100.0
Auglaize	28,037	30,637	36,147	38,602	16,126	41.8	400	341	85.3
Defiance	24,367	25,925	31,508	36,949	19,742	53.4	412	412	100.0
Fulton	23,626	25,580	29,301	33,071	13,450	40.7	407	333	81.7
Hancock	40,793	44,280	53,686	61,217	38,897	63.5	532	392	73.7
Henry	22,756	22,423	25,392	27,058	7,791	28.8	416	416	100.0
Lucas	344,333	395,551	456,931	483,594	56,008	94.1	343	154	44.8
Mercer	26,256	28,311	32,559	35,558	11,312	32.1	444	212	46.3
Paulding	15,527	15,047	16,792	19,329	2,983	15.4	417	417	100.0
Putnam	25,016	25,248	28,331	31,134	3,622	11.6	486	486	100.0
Van Wert	26,759	26,971	28,840	29,194	14,627	50.1	409	409	100.0
Williams	25,510	26,202	29,968	33,669	11,192	33.2	421	421	100.0
Wood	51,796	59,605	72,596	89,722	48,582	54.1	619	193	31.3

To Convert From	To	Multiply By
Square Miles (sq mi)	Square Kilometers (sq km)	2.59

TABLE 6. LAND USE IN THE MAUMEE AND PORTAGE RIVER BASINS BY SUBBASIN (RESOURCE MANAGEMENT ASSOCIATES, WEST CHESTER, PA.)

St. Joseph River Basin

Land Use	Area Hectares	Percent of Total Area
Single-Family Residential	8496	2.89
Multiple-Family Residential	72	0.02
Mobile Home	36	0.01
Commercial and Services	612	0.21
Industrial	432	0.15
Institutional	468	0.16
Extractive	216	0.07
Urban Open Space	2016	0.69
Other Urban	180	0.06
Cropland, Undifferentiated	200412	68.16
Truck Crops	36	0.01
Orchards and Bush-Fruit	72	0.02
Horticulture	72	0.02
Old Field Vegetation	252	0.09
Farmsteads	1548	0.53
Row Crops	144	0.05
Field Crops	36	0.01
Brushland	9756	3.32
Deciduous Forest	38916	13.24
Rivers and Streams	7812	2.66
Lakes	2376	0.81
Reservoirs	1044	0.36
Wetlands, Forested	720	0.24
Wetlands, Non-Forested	1080	0.37
Construction Activity	324	0.11
Improved Roads	14940	5.08
Unimproved Roads	468	0.16
Railroads	1332	0.45
Airports	108	0.04
Utilities	36	0.01
Total area	294,012	

St. Marys River Basin

Land Use	Area Hectares	Percent of Total Area
Residential, Undifferentiated	36	0.02
Single-Family Residential	6300	3.01
Multiple-Family Residential	108	0.05
Mobile Home	108	0.05
Commercial and Services	792	0.38
Industrial	576	0.27
Institutional	720	0.34

TABLE 6. (CONT.)

Land Use	Area Hectares	Percent of Total Area
Extractive	396	0.19
Urban Open Space	1512	0.72
Cropland, Undifferentiated	158562	75.69
Truck Crops	36	0.02
Orchards and Bush-Fruit	108	0.05
Old Field Vegetation	36	0.02
Farmsteads	1728	0.82
Brushland	2664	1.27
Deciduous Forest	15813	7.55
Rivers and Streams	6084	2.90
Lakes	2376	1.13
Reservoirs	360	0.17
Wetlands, Forested	648	0.31
Wetlands, Non-Forested	72	0.03
Beaches, Mudflats ,and Unvegetated Areas	36	0.02
Construction Activity	36	0.02
Improved Roads	9261	4.42
Unimproved Roads	216	0.10
Railroads	720	0.34
Airports	72	0.03
Utilities	108	0.05
Total area	209,484	

Blanchard River Basin

Land Use	Area Hectares	Percent of Total Area
Single-Family Residential	1800	1.47
Commercial and Services	108	0.09
Industrial	144	0.12
Institutional	72	0.06
Extractive	270	0.22
Urban Open Space	396	0.32
Cropland, Undifferentiated	92961	75.90
Truck Crops	900	0.73
Orchards and Bush-Fruit	9	0.01
Old Field Vegetation	108	0.09
Feedlots	36	0.03
Farmsteads	1314	1.07
Other Agriculture Land	36	0.03
Row Crops	3240	2.65
Field Crops	1314	1.07
Brushland	882	0.72
Deciduous Forest	7668	6.26
Coniferous Forest	72	0.06

TABLE 6. (CONT.)

Land Use	Area Hectares	Percent of Total Area
Mixed Forest	54	0.04
Rivers and Streams	3690	3.01
Lakes	72	0.06
Reservoirs	144	0.12
Wetlands, Forested	36	0.03
Wetlands, Non-Forested	108	0.09
Improved Roads	5850	4.78
Unimproved Roads	216	0.18
Railroads	891	0.73
Airports	72	0.06
Utilities	9	0.01
Total area	122,472	

Auglaize River Basin (Except Blanchard)

Land Use	Area Hectares	Percent of Total Area
Single-Family Residential	12708	2.92
Multiple-Family Residential	72	0.02
Mobile Home	108	0.02
Commercial and Services	684	0.16
Industrial	2196	0.50
Institutional	720	0.17
Extractive	684	0.16
Urban Open Space	3132	0.72
Cropland, Undifferentiated	336960	77.44
Truck Crops	108	0.02
Orchards and Bush-Fruit	36	0.01
Old Field Vegetation	252	0.06
Farmsteads	3024	0.70
Other Agriculture Land	36	0.01
Brushland	3600	0.83
Deciduous Forest	30456	7.00
Unidentified	36	0.01
Rivers and Streams	12672	2.91
Lakes	576	0.13
Reservoirs	1656	0.38
Wetlands, Forested	324	0.07
Wetlands, Non-Forested	144	0.03
Beaches, Mudflats, and Unvegetated Areas	36	0.01
Construction Activity	144	0.03
Improved Roads	21456	4.93
Unimproved Roads	432	0.10
Railroads	2592	0.60
Airports	72	0.02
Utilities	180	0.04
Total area	435,096	

TABLE 6. (CONT.)

Maumee Direct Drainage Above Defiance

Land Use	Area Hectares	Percent of Total Area
Single-Family Residential	4176	5.31
Multiple-Family Residential	108	0.14
Mobile Home	72	0.09
Commercial and Services	468	0.60
Industrial	540	0.69
Institutional	216	0.27
Extractive	108	0.14
Urban Open Space	1296	1.65
Cropland, Undifferentiated	55224	70.25
Farmsteads	468	0.60
Row Crops	9	0.01
Field Crops	9	0.01
Brushland	1080	1.37
Deciduous Forest	6300	8.01
Rivers and Streams	2700	3.43
Lakes	72	0.09
Reservoirs	216	0.27
Wetlands, Forested	36	0.05
Wetlands, Non-Forested	36	0.05
Construction Activity	180	0.23
Improved Roads	4248	5.40
Unimproved Roads	144	0.18
Railroads	612	0.78
Airports	216	0.27
Utilities	72	0.09
Total area	78,606	

Tiffin River Basin

Land Use	Area Hectares	Percent of Total Area
Single-Family Residential	4284	2.18
Commercial and Services	396	0.20
Industrial	288	0.15
Institutional	288	0.15
Extractive	36	0.02
Urban Open Space	612	0.31
Cropland, Undifferentiated	143856	73.19
Orchards and Bush-Fruit	36	0.02
Old Field Vegetation	72	0.04
Feedlots	36	0.02
Farmsteads	1476	0.75

TABLE 6 (CONT.)

Land Use	Area Hectares	Percent of Total Area
Brushland	4320	2.20
Strip Cropping	36	0.02
Deciduous Forest	21168	10.77
Coniferous Forest	108	0.05
Rivers and Streams	6120	3.11
Lakes	756	0.38
Reservoirs	360	0.18
Unidentified	36	0.02
Wetlands, Forested	288	0.15
Wetlands, Non-Forested	288	0.15
Construction Activity	288	0.15
Improved Roads	10116	5.15
Unimproved Roads	540	0.27
Railroads	576	0.29
Airports	108	0.05
Utilities	72	0.04
Total area	196,560	

Maumee Below Waterville

Land Use	Area Hectares	Percent of Total Area
Single-Family Residential	816	4.11
Mobile Home	72	0.36
Institutional	36	0.18
Urban Open Space	252	1.27
Cropland, Undifferentiated	13720	69.11
Old Field Vegetation	36	0.18
Farmsteads	360	1.81
Brushland	288	1.45
Deciduous Forest	2436	12.27
Rivers and Streams	540	2.72
Reservoirs	72	0.36
Improved Roads	972	4.90
Railroads	252	1.27
Total area	19,852	

TABLE 6. (CONT)

Entire Maumee Basin

Land Use	Area Hectares	Percent of Total Area
Residential, Undifferentiated	36	<0.01
Single-Family Residential	41796	2.75
Multiple-Family Residential	360	0.02
Mobile Home	396	0.03
Commercial and Services	3492	0.23
Industrial	4392	0.29
Institutional	2628	0.17
Extractive	1710	0.11
Urban Open Space	10260	0.68
Other Urban	216	0.01
Cropland, Undifferentiated	1133227	74.67
Truck Crops	1296	0.09
Orchards and Bush-Fruit	261	0.02
Horticulture	72	0.00
Old Field Vegetation	792	0.05
Feedlots	72	<0.01
Farmsteads	11658	0.77
Other Agriculture Land	108	0.01
Row Crops	3393	0.22
Field Crops	1359	0.09
Brushland	23346	1.54
Strip Cropping	36	<0.01
Deciduous Forest	130265	8.58
Coniferous Forest	180	0.01
Mixed Forest	54	<0.01
Unidentified	36	<0.01
Rivers and Streams	44110	2.91
Lakes	6228	0.41
Reservoirs	4284	0.28
Unidentified	36	<0.01
Wetlands, Forested	2196	0.14
Wetlands, Non-Forested	1728	0.11
Beaches, Mudflats, and Unvegetated Areas	108	0.01
Construction Activity	1116	0.07
Improved Roads	74943	4.94
Unimproved Roads	2196	0.14
Railroads	7947	0.52
Airports	792	0.05
Utilities	549	0.04
Total area	1,517,674	

TABLE 6. (CONT)

Portage Below Woodville

Land Use	Area Hectares	Percent of Total Area
Single-Family Residential	716	2.04
Multiple-Family Residential	4	0.01
Mobile Home	40	0.11
Commercial and Services	104	0.30
Industrial	64	0.18
Institutional	72	0.21
Extractive	152	0.43
Urban Open Space	252	0.72
Other Urban	32	0.09
Disrupted Cropland	220	0.63
Cropland, Undifferentiated	25189	71.75
Truck Crops	564	1.61
Orchards and Bush-Fruit	64	0.18
Old Field Vegetation	336	0.96
Farmsteads	664	1.89
Other Agriculture Land	144	0.41
Brushland	648	1.85
Deciduous Forest	2852	8.12
Rivers and Streams	1368	3.90
Lakes	112	0.32
Wetlands, Forested	260	0.74
Wetlands, Non-Forested	296	0.84
Beaches, Mudflats, and Unvegetated Areas	32	0.09
Construction Activity	8	0.02
Improved Roads	736	2.10
Unimproved Roads	44	0.13
Railroads	124	0.35
Utilities	8	0.02
Total area	35,105	

Portage Above Woodville

Land Use	Area Hectares	Percent of Total Area
Unidentified	4	<0.01
Unidentified	4	<0.01
Single-Family Residential	1364	1.31
Multiple-Family Residential	8	0.01
Mobile Home	8	0.01
Commercial and Services	111	0.11
Industrial	354	0.34
Institutional	108	0.10
Extractive	97	0.09

TABLE 6. (CONT.)

Land Use	Area Hectares	Percent of Total Area
Urban Open Space	674	0.65
Other Urban	87	0.08
Disrupted Cropland	6277	6.02
Cropland, Undifferentiated	81805	78.48
Truck Crops	334	0.32
Horticulture	92	0.09
Old Field Vegetation	196	0.19
Feedlots	8	0.01
Farmsteads	1441	1.38
Other Agriculture Land	559	0.54
Brushland	960	0.92
Unidentified	4	0.00
Unidentified	4	0.00
Deciduous Forest	6063	5.82
Rivers and Streams	722	0.69
Lakes	322	0.31
Wetlands, Forested	12	0.01
Wetlands, Non-Forested	42	0.04
Beaches, Mudflats, and Unvegetated Areas	33	0.03
Construction Activity	28	0.03
Improved Roads	2131	2.04
Unimproved Roads	80	0.08
Railroads	292	0.28
Utilities	12	0.01
Total area	10,4236	

Entire Portage Basin

Land Use	Area Hectares	Percent of Total Area
Unidentified	4	<0.01
Unidentified	4	<0.01
Single-Family Residential	2080	1.49
Multiple-Family Residential	12	0.01
Mobile Home	48	0.03
Commercial and Services	215	0.15
Industrial	418	0.30
Institutional	180	0.13
Extractive	249	0.18
Urban Open Space	926	0.66
Other Urban	119	0.09
Disrupted Cropland	6497	4.66
Cropland, Undifferentiated	106994	76.79
Truck Crops	898	0.64
Orchards and Bush-Fruit	64	0.05

TABLE 6. (CONT.)

Land Use	Area Hectares	Percent of Total Area
Horticulture	92	0.07
Old Field Vegetation	532	0.38
Feedlots	8	0.01
Farmsteads	2105	1.51
Other Agriculture Land	703	0.50
Brushland	1608	1.15
Unidentified	4	0.01
Unidentified	4	0.01
Deciduous Forest	8915	6.40
Rivers and Streams	2090	1.50
Lakes	434	0.31
Wetlands, Forested	272	0.20
Wetlands, Non-Forested	338	0.24
Beaches, Mudflats,and Unvegetated Areas	65	0.05
Construction Activity	36	0.03
Improved Roads	2867	2.06
Unimproved Roads	124	0.09
Railroads	416	0.30
Utilities	20	0.01
Total area	139,341	

TABLE 7. AGRICULTURAL LAND USE IN PLANNING SUBAREA 4.2 (PLUARG TASK B)

Crop	Current Normal[1/]	
	Acres 2/	Hectares 2/
Wheat	509.5	206.2
Oats	207.2	83.9
Rye	9.1	3.7
Barley	2.5	1.0
Misc. Small Grains	0	0
Corn for Grain	1,201.0	486.0
Corn Silage	66.7	27.0
Soybean	1,526.2	617.6
Dry E. D. Beans	0	0
Sugar Beets	33.6	13.6
Potatoes	4.3	1.7
Fruits	10.9	4.4
Comm. Vegetables	44.4	18.0
Comm. Sod	0.9	0.4
Alfalfa Hay	258.4	104.6
Clover & Timothy Hay	185.9	75.2
Cropland Pasture	92.9	37.6
Idle Cropland	581.6	235.4
Total Cropland	4,735.1	1,916.3
Improved Pasture	81.3	32.9
Improved Pasture	132.5	53.6
N. Improved Pasture		
Total Pasture	213.8	86.5
Total Ag. Land[3/]	4,948.9	2,002.8

1/ Current normal represents present **area** estimate based on 1958-1972 average
2/ Measurement is in thousands of acres or hectares
3/ Totals may not add due to rounding

TABLE 8. CROP PRODUCTION IN THE MAUMEE RIVER BASIN - ACRES HARVESTED (1975-1976)

	Crop				
County	Corn	Soybeans	Wheat	Oats	Hay
Allen, Oh.	59,550	63,250	36,300	7,000	9,250
Defiance, Oh.	39,950	75,100	44,650	10,900	6,600
Fulton, Oh.	95,800	56,300	31,850	5,550	8,750
Hancock, Oh.	82,950	109,500	66,600	6,800	12,500
Henry, Oh.	77,550	86,250	47,300	9,000	10,350
Lucas, Oh.	27,550	34,700	13,650	1,600	3,050
Paulding, Oh.	51,050	82,650	46,800	18,400	6,450
Putnam, Oh.	74,400	100,600	52,100	8,800	15,950
Van Wert, Oh.	80,000	102,400	41,000	10,100	6,600
Williams, Oh.	59,250	58,150	42,900	8,700	11,850
Wood, Oh.	107,250	113,150	73,850	15,200	17,150
Auglaize, Oh.	67,200	58,250	33,100	13,700	21,400
Hardin, Oh.	79,950	89,050	47,600	11,300	14,700
Mercer, Oh.	81,500	78,000	40,150	20,900	25,200
Hillsdale, Mi.	84,600	24,345	23,515	8,380*	28,573†
Lenawee, Mi.	121,120	86,050	61,060	13,500*	16,649†
DeKalb, Ind.	49,500	39,700	19,500	6,300	12,600
Allen, Ind.	89,300	83,200	42,300	13,800	14,500
Adams, Ind.	60,900	62,900	27,700	6,700	11,200

* 1974-1975

† 1974 Census of Agriculture

The resulting rotation is: C O Sb W

3. The remaining corn and soybeans after 2 is in corn-soybean rotation: C Sb
4. Any remaining corn or soybeans after 3 is: Cont. C or Cont. Sb.
5. 50% of acres of hay harvested is in permanent pasture
6. All other crops are ignored because a very small percentage of total cropland is involved.

Rotations:

1. C Sb W
2. C Sb W M
3. C O Sb W
4. C Sb
5. Cont C
6. Cont Sb
7. Permanent Pasture

The first assumption is not strictly true when the data are to be used calculation of soil loss estimates. This is especially true when the county is in an uplands section of the watershed and portions of the county are hilly, while other areas may be very flat. This effect will be partially offset by weighting the rotations, which include winter cover, spring plowing, and meadow, toward the soils which are known to occur on a rolling landscape.

Assumption 2 is obvious from the magnitude of the production of these crops. Almost all farmers in the Basin attempt to utilize this profitable rotation. Assumptions 2A and 2B are known to be predominant alternatives. The 50% of acres of hay harvested is an arbitrary figure which will be lower in uplands counties where permanent pasture is more important, and higher in lakebed and till-plain areas where there is very little permanent pasture. Assumption 5 follows directly and includes the remainder of the acres of hay harvested in permanent pasture. Assumption 2B is a common alternative for the inclusion of oats in a rotation. Following oats, the field is planted to winter wheat. All oats are included in this rotation. The resultant rotation is corn-soybeans-oats-wheat.

Assumption 3 places the remainder of the corn and soybeans, except for the absolute difference between the acreage in corn and soybeans, into a corn-soybean rotation. Assumption 4 places the difference between corn and soybean acreage harvested, whichever is greater, into monoculture of that crop: continuous corn or continuous soybeans.

The last assumption places all cropland into production of the five major crops. As stated earlier, the production of sugar beets and vegetables is economically important in the Basin but accounts for less than 5% of the cropland in any of the counties.

These assumptions provide seven equations in seven unknowns to calculate the seven major rotations found in the watershed:

(C O Sb W) = Oats x 4
(C Sb W M) = (.5 (Hay)) x 4
(Permanent Pastures) = (.5 (Hay)) x 1
(C Sb W) = ((Wheat) - (Oats + 0.5 Hay)) x 3
(C Sb) = ((lesser of C or Sb) - Wheat) x 2
if C Sb
(Cont. Sb) = (Soybeans - Corn) x 1
if Sb C
(Cont. Corn) = (Corn - Soybeans) x 1

Each result is multiplied by the number of years in the rotation (e.g. there are four years in C SG O W rotation) and gives the average number of acres in each of the seven rotations in each county in a given year. Table 9 lists the results of the calculations.

4.24 Tillage practices and timing of farm operations

The nature and timing of tillage operations in the Maumee River Basin are influenced, as they are anywhere, by the nature of the soils, weather patterns, and prevailing popular notions. Most soils are wet and difficult to till during the spring. Since crop yields are significantly reduced by late planting, most farmers take the opportunity of dry fall weather to plow their land and reduce the risk of losses due to a wet spring. The moldboard plow is by far the predominant tillage implement.

USDA-SCS District Conservationists were surveyed in an earlier study of erosion in the Maumee River Basin (Maumee Level B Study Erosion and Sedimentation Technical Report, 1975) as to the extent of common tillage practices in each county in the Basin. Table 10 lists the results of that survey. Some changes in the originally published table have been made as a result of further interviews taken during this study with agronomists familiar with the Basin.

It is apparent that conventional fall tillage with the moldboard plow is by far the dominant practice, with 60% of the cropland in the Basin being tilled in this manner. With the emergence of powerful tractors capable of plowing more land at a very high rate of speed, it is also apparent that the percentage of fall-plowed land will continue to grow for at least several years.

The third column represents a form of tillage which is growing rapidly in the Maumee Basin; it is usually applied on land to be planted to winter wheat following soybeans. This system is growing in popularity because it is accomplished rapidly and permits earlier planting of wheat. The system is also amenable to till-plant systems in which tillage, fertilization, and planting are accomplished in a single operation. Unfortunately there is some question as to whether or not this form of reduced tillage reduces soil loss. Approximately 30% of the soybean residue is incorporated, leaving a mulch of only about 1600 lbs/acre or approximately 30% surface coverage. Mannering and Johnson (1975) have reported that low percentages of residue cover in fall reduced-tillage systems may be less effective in controlling soil loss than conventional fall tillage due to the offsetting effect of roughness obtained in plowing.

TABLE 9. ACREAGE OF MAJOR ROTATION BY COUNTY IN THE MAUMEE RIVER BASIN.

County *	C Sb W	C Sb W M	C O Sb W	C Sb	Cont. C	Cont. Sb.	Permanent Pasture
Allen	74,025	18,500	28,000	46,500	--	3,700	4,625
Defiance	86,650	13,200	43,600	--	--	35,150	3,300
Fulton	65,775	17,500	22,200	48,900	39,500	--	4,375
Hancock	160,650	25,000	27,200	32,700	--	26,550	6,250
Henry	99,375	20,700	36,300	60,500	--	8,700	5,175
Lucas	31,575	6,100	6,400	27,800	--	7,150	1,525
Paulding	75,525	12,900	73,600	8,500	--	31,600	3,225
Putnam	105,975	31,900	35,200	44,600	--	26,200	7,975
Van Wert	82,800	13,200	40,400	78,000	--	22,400	3,300
Williams	84,825	23,700	34,800	30,500	1,100	--	5,925
Wood	150,225	34,300	60,800	66,800	--	5,900	8,575
Auglaize	26,100	42,800	54,800	50,840	8,680	--	10,700
Hardin	86,850	29,400	45,200	64,700	--	9,100	7,350
Mercer	19,950	50,400	83,600	75,700	3,500	--	12,600
Hillsdale, Mi.	2,545	57,146	33,520	1,660	60,255	--	14,287
Lenawee, Mi.	113,200	39,300	54,000	49,980	35,070	--	9,825
DeKalb, Ind.	20,700	25,200	25,200	40,400	9,800	--	6,300
Allen, Ind.	63,750	29,000	55,200	81,800	6,100	--	7,250

*Ohio, unless otherwise indicated.

TABLE 10. TILLAGE FRACTIONS USED IN THE BASIN (%OF COUNTY)

	1	2	3	4	5
Allen, Oh.	39	50	10	1	0
Defiance, Oh.	10	89	0	1	0
Fulton, Oh.	40	50	9	1	0
Hancock, Oh.	10	65	5	5	15 (6)*
Henry, Oh.	28	70	0	0	2 (2)
Lucas, Oh.	25	65	10	0	0
Paulding, Oh.	5	95	0	0	0
Putnam, Oh.	30	50	15	5	0
Van Wert, Oh.	20	55	3	2	20 (4)
Williams, Oh.	15	85	0	0	0
Wood, Oh.	10	69	20	1	0
Auglaize, Oh.	54	40	5	1	0
Hardin, Oh.	38	60	1	1	0
Mercer, Oh.	34	62	3	1	0
Hillsdale, Mi.	70	27	2	1	0
Lenawee, Mi.	39	50	5	1	5 (5)
De Kalb, Ind.	40	45	0	5	10 (3)
Allen, Ind.	10	60	20	2	8 (1)
Adams, Ind.	35	60	3	2	0

1. Conventional, Spring Plow, Plant, Cultivate
2. Conventional, Fall Plow, Plant, Cultivate
3. Disk, Plant, Cultivate (minimum tillage)
4. No tillage
5. Other forms of minimum tillage. Number in parentheses indicates type of tillage reported.* (1 - chisel plow, disc and plant; 2 - fall chisel plow; 3 - chisel plow; 4 - fall chisel plow; 5 - field cultivate; 6 - fall and spring chisel plow)

4.25 Livestock

Table 11 summarizes livestock production in Maumee River Basin counties. Mercer County is the major poultry producer, while Fulton County is the major cattle (primarily dairy) and swine producer. Most livestock operations in the Basin are confined systems. Loss of nutrients from improper handling of wastes can be a localized problem but does not appear to greatly contribute to nutrient loads in the Maumee Basin.

4.26 Point Sources

Urban and rural nonfarm land use has been studied extensively by others (TMACOG Sec. 208, Maumee Level B study, LEWMS) and will not be discussed here. The major point source discharges above Waterville are at Fort Wayne and Lima. The City of Toledo is the major point source in the Basin but is not included in Waterville loadings since it lies below Waterville. Toledo's input of nutrients must be considered a major source of nutrients to the Western Basin of Lake Erie because of its proximity to the lake.

4.3 Soils in the Maumee River Basin

The soils of the Maumee River Basin are developed under glacial deposits of recent origin. The last phases of the late Wisconsin glacial period occurred less than 8000 years ago. Soil parent materials can be divided into four groups:

- glacial till associated with the various moraines in the Basin and also intermorainal areas

- lacustrine sediments in the Lake Plain region

- beach ridges associated with the glacial Lake Maumee

- stream alluvial deposits.

Figure 22 (Black Creek study, 1977) shows the distribution of major soil associations in the Basin. The Morley-Blount-Pewamo and Blount-Pewamo associations account for the greatest acreage of soils in the Basin. Formed in glacial till, they occur along the perimeter of the Basin and constitute the more sloping region of the watershed. The Hoytville-Toledo-Napanee association occurs in the central basin and is formed from till and lacustrine materials. In the center of the Basin, the Paulding-Latty-Roselms association occurs in the Lake Plain. Table 12 identifies the major soil series and their percentages in the entire Basin and in the Ohio area.

The Maumee Basin soils are very fertile. Because of their youthful nature, they are high in native fertility. Intensive crop production in the Basin has been achieved over the last 70-80 years by extensive drainage of these poorly drained soils. While this vast network of surface and tile drains, man-made ditches, and modified natural streams has made cultivation of these soils possible, there is little doubt that this has contributed to an acceleration of sediment transport in the Basin. The major soils of the Basin are high in clay and, therefore, most susceptible to transport once they are eroded.

TABLE 11. INTENSIVE LIVESTOCK OPERATIONS BY COUNTY, 1969 (PLUARG TASK B)

	Estimated Livestock Total						Estimated Animal Waste		
	Poultry		Cattle		Swine		Wet Lbs/Day		
	No. Farms	Number	No. Farms	Number	No. Farms	Number	Poultry	Cattle	Swine
PSA 4.2									
Indiana									
Adams	24	480,000	26	3,978	87	29,851	148,924	198,900	298,510
Allen	10	298,030	43	8,107	87	31,828	89,599	495,350	318,280
De Kalb	1	10,000	34	6,061	40	12,982	3,100	303,050	129,820
Ohio									
Allen	8	176,372	37	6,286	41	12,316	54,675	314,300	123,160
Auglaize	2	20,000	43	8,141	70	24,647	6,200	407,050	246,470
Defiance	3	68,500	20	3,507	28	12,529	21,235	175,350	125,290
Fulton	19	316,364	122	27,060	111	45,209	98,072	1,353,000	452,090
Hancock	7	130,384	32	6,895	43	16,131	40,419	344,750	161,310
Henry	8	189,826	21	5,086	31	10,759	58,846	254,300	107,590
Lucas	1	10,000	11	2,534	17	5,549	3,100	126,700	55,490
Mercer	29	716,834	34	4,856	121	39,166	222,218	242,800	391,660
Paulding	2	20,000	8	957	5	1,779	6,200	47,850	17,790
Putnam	15	200,132	28	4,801	72	23,846	62,040	240,050	238,460
Van Wert	4	46,600	4	400	23	6,461	14,446	20,000	64,610
Williams	5	55,500	66	12,458	38	14,557	17,205	622,900	145,570
Wood	3	43,760	59	11,040	22	8,838	13,565	522,000	88,380

To Convert From	To	Multiply By
Pounds (lb)	Kilograms (kg)	0.454

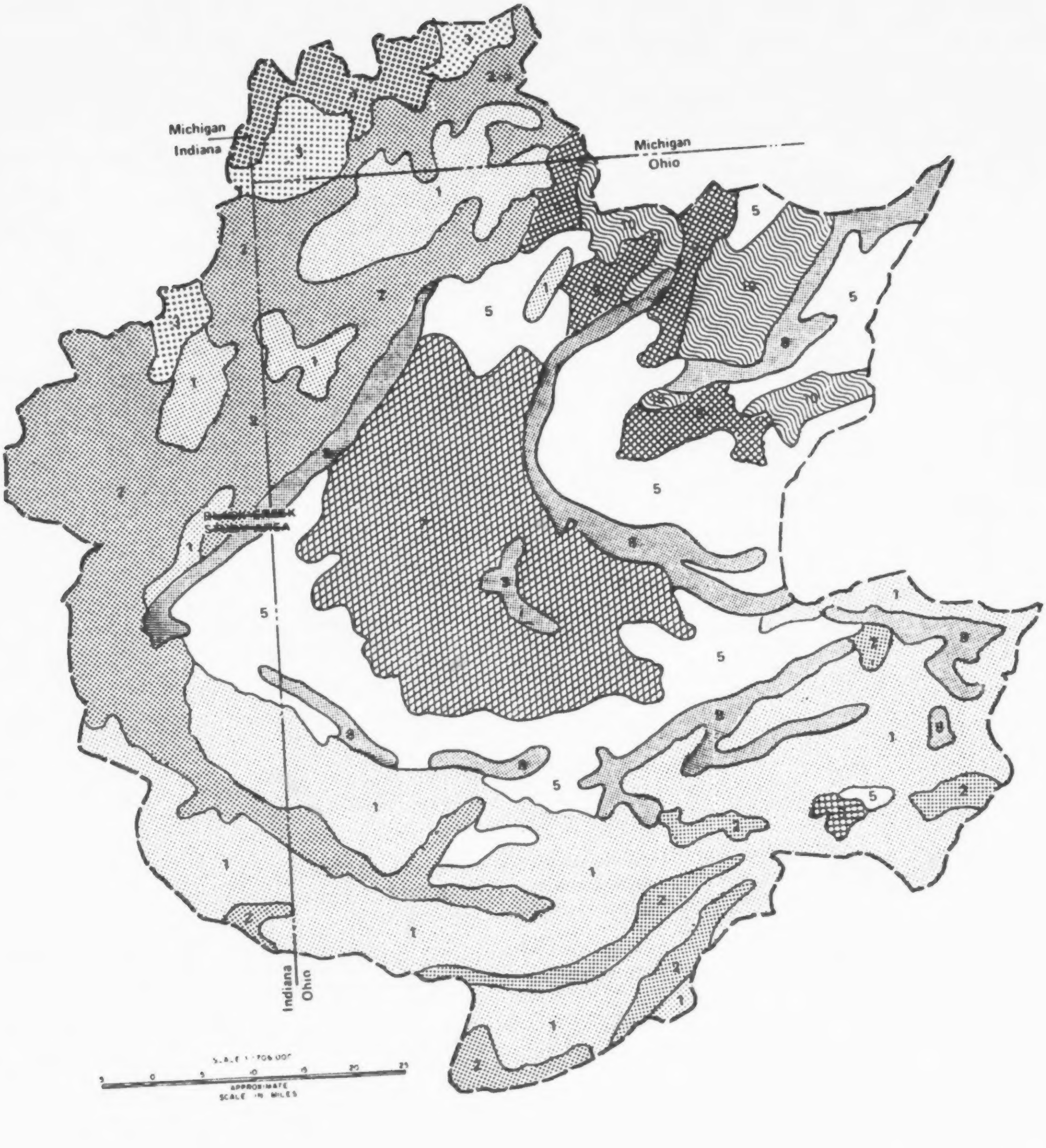
Michigan
Indiana
Michigan
Ohio
Indiana
Ohio
5 0 5 10 15 20 25
APPROXIMATE
SCALE IN MILES

FIGURE 22. SOIL ASSOCIATIONS IN THE MAUMEE RIVER BASIN (BLACK CREEK REPORT, 1977).

LEGEND
SOILS DOMINANTLY FORMED IN GLACIAL TILL

1 ░ BLOUNT-PEWAMO ASSOCIATION: Depressional to gently sloping, very poorly drained to somewhat poorly drained soils that have clayey subsoils.

2 ▒ MORLEY-BLOUNT-PEWAMO ASSOCIATION: Depressional to moderately steep, very poorly drained to moderately well-drained soils that have clayey subsoils.

3 ░ MIAMI-CONOVER ASSOCIATION: Nearly level to moderately steep, well-drained and somewhat poorly drained soils that have loamy subsoils.

4 ▒ HILLSDALE-FOX ASSOCIATION: Gently sloping to moderately steep, well-drained soils that have loamy subsoils.

5 □ HOYTVILLE-TOLEDO-NAPPANEE ASSOCIATION: Depressional to gently sloping, very poorly drained and somewhat poorly drained soils that have clayey subsoils.

SOILS DOMINANTLY FORMED IN WATER-DEPOSITED MATERIAL, ORGANIC MATERIAL, AND EOLIAN MATERIAL

6 ▓ CARLISLE-MONTGOMERY ASSOCIATION: Depressional and nearly level, very poorly drained soils that have organic and clayey subsoils.

7 ▓ PAULDING-LATTY-ROSELMS ASSOCIATION: Depressional and nearly level, very poorly drained and somewhat poorly drained soils that have clayey subsoils.

8 ▒ HANEY-BELLMORE-MILLGROVE ASSOCIATION: Depressional to strongly sloping, very poorly drained, moderately well-drained, and well-drained soils that have loamy subsoils.

9 ▓ MERMILL-HASKINS-WAUSEON ASSOCIATION: Depressional and nearly level, very poorly drained and somewhat poorly drained soils that have loamy and clayey subsoils.

10 ≋ OTTOKEE-GRANBY ASSOCIATION: Depressional to sloping, very poorly drained, poorly drained, moderately well-drained soils that have sandy subsoils.

FIGURE 22. (CONTINUED)

TABLE 12. ACREAGE OF MAJOR SOIL SERIES IN THE MAUMEE RIVER BASIN (SERIES WITH MORE THAN 10,000 HECTARES)†

Soil Series	Area Hectares	Percent of Total Area
Blount	217,679	14.34
Hoytville	165,480	10.90
Pewamo	165,396	10.90
Fremont-Volusia*	115,309	7.60*
Paulding	65,772	4.33
Latty	52,299	3.45
Morley	49,410	3.26
Nappanee	34,520	2.27
Millgrove	28,234	1.86
Roselms	24,120	1.59
Sloan	23,595	1.55
Lenawee	21,348	1.41
Glynwood	16,209	1.07
Mermill	13,887	0.92
Fulton	13,284	0.88
Miami	13,140	0.87
Wauseon	13,024	0.86
Toledo	10,953	0.72
	1,043,659	68.78%

---

*Includes Brookston, Toledo and other dark-colored soils.

†Unpublished data. Lake Erie Wastewater Management Study, Corps of Engineers, Buffalo District, Buffalo, N.Y.

Erosion and subsequent sediment transport are a function not only of slope but also the infiltration capacity of these soils during different times of the year. Slope is a major factor in the till-plain regions of the Basin, which constitute the Basin perimeter, while the more level lake plains soils are greatly affected by antecedent moisture prior to rainfall and snow-melt and the effectiveness of drainage systems in removing excess water. These factors will be discussed later. More detailed description of soil properties are given in Volume 2 of this Report.

4.4 Loading results

4.41 Defiance Watersheds and Hoytville Plots

Precipitation and flow from the various sites are given in Table 13 . Monitoring began in April 1975 on the Hoytville plots and in July and August on the Defiance watersheds. Summer rain was above normal in 1975. 1976 was somewhat of a dry year, and 1977 was normal. Surface runoff was highest on the sloping Roselms soil and the level Paulding soil. The Blount soil was intermediate as was Hoytville, while the Lenawee soil had very little surface runoff. Tile flow was highest on the Hoytville soil and lowest on the Paulding. On the level Lenawee, Hoytville and Paulding soils, surface runoff was inversely related to tile drainage, the more poorly structured Paulding soil giving very little tile flow and the highest surface runoff. Tile drainage, therefore, would appear to reduce surface runoff on those soils which have sufficient hydraulic conductivity to respond to tile drainage. On all sites, both surface runoff and tile drainage were concentrated in the spring months from the first thaw through May. During this period, soils are saturated and infiltration is minimal.

Soil and nutrient losses for each site are given in Tables 14-23. The results from the Hoytville plots were averaged, since there were no significant differences among the various tillage treatments. Surface runoff on the Hoytville plots (Table 22) was low enough that tillage had little effect on soil or nutrient loss.

Sediment - Soil loss was highest on the Paulding site in all years, followed by the more sloping Roselms and Blount sites, while losses from the Lenawee and Hoytville soils were minimal. From the standpoint of best management practices to reduce soil loss, no-tillage is feasible on the Blount soil if it is tile-drained, and chisel-plow can be used on the Roselms. Lenawee and Hoytville require no conservation tillage if they are drained. Paulding soil remains the greatest problem because this soil does not respond to tile drainage and is probably too poorly drained for reduced tillage. Sediment in tile was low on all sites ($<$ 250 kg/ha).

Phosphorus - Most of the P loss in surface runoff occurred as sediment-P and, therefore, followed soil loss closely. As a result, total-P loss was highest on the Paulding soil. Soluble-P moves very slowly through soil, and most of the P loss by tile drainage was sediment-P. The Hoytville plots were the only sites to receive significant amounts of P fertilizer, and there was an increasing trend for filtered reactive-P and total-P loss in runoff and tile flow from 1975 to 1977.

TABLE 13. FLOW AND PRECIPITATION AT DEFIANCE WATERSHEDS AND HOYTVILLE PLOTS (1975-1977)

	1975*		1976		1977 †	
	Flow	Ppt	Flow	Ppt	Flow	Ppt
	centimeters					
111[§]	7.6	42.4	36.1	66.2	17.8	35.4
201	14.1	42.8	16.5	66.7	30.1	38.3
301	0.0	42.6	2.6	59.2	6.4	32.1
302	10.2	42.6	9.0	59.2	7.0	32.1
401	5.0	39.8	15.6	66.1	17.6	34.5
402	5.8	43.8	11.5	66.1	9.3	34.5
501	19.9	52.1	23.4	61.5	39.4	35.8
502	0.9	52.1	2.8	61.5	0.0	35.8
6×1	4.7 ‡	79.4	19.1	67.9	11.2	94.4
6×2	24.3 ‡	79.4	22.8	67.9	25.7	94.4

* Monitoring began in April on Hoytville plots (6×1, 6×2) and in July and August on the other watersheds.

† Monitoring was terminated May 31 on all sites except the Hoytville plots.

‡ Values given are means of all eight plots.

§ See Table 1 for plot designations.

TABLE 14. CONCENTRATION AND LOAD OF POLLUTANTS FROM HAMMERSMITH ROSELMS (111) SURFACE RUNOFF

	1975				1976				1977			
	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load
	High	Low	FWM+	(kg/ha)	High	Low	FWM	(kg/ha)	High	Low	FWM	(kg/ha)
Sediment	5850	242	2235	1785	4647	39	1156	3714	6560	202	809	1284
Filtered reactive-P	0.36	0.01	0.08	0.06	0.25	0.0	0.05	0.18	0.05	0.01	0.03	0.04
Total-P	3.45	0.22	1.35	0.83	3.90	0.00	0.76	2.15	2.08	0.26	0.78	1.24
(Nitrate + nitrite)-N	9.2	0.0	2.9	2.0	27.6	0.0	6.2	19.9	9.0	2.0	5.7	9.0
Ammonia-N	5.3	0.0	0.9	0.4	4.1	0.0	0.7	1.5	0.0	0.0	0.0	0.0
Total-N	19.8	1.6	8.0	5.4	39.8	0.0	8.6	27.6	21.8*	0.6*	4.2*	6.6*

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* In 1977, TKN was measured instead of total-N

+ Flow weighted mean concentration (FWM)

TABLE 15. CONCENTRATION AND LOAD OF POLLUTANTS FROM CRITES ROSELMS (201) SURFACE RUNOFF

	1975				1976				1977			
	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load
	High	Low	FWM+	(kg/ha)	High	Low	FWM	(kg/ha)	High	Low	FWM	(kg/ha)
Sediment	8010	311	4596	5085	10496	75	1563	2294	5091	118	722	1938
Filtered reactive-P	0.56	0.02	0.08	0.10	0.19	0.00	0.07	0.10	0.07	0.01	0.02	0.06
Total-P	6.40	0.11	1.24	1.37	7.80	0.00	1.26	1.60	3.17	0.26	0.79	2.11
(Nitrate + nitrite)-N	9.5	0.0	4.3	4.9	15.4	0.0	5.0	7.3	5.0	0.0	2.2	4.9
Ammonia-N	4.1	0.0	2.0	1.9	1.7	0.0	0.4	0.7	0.0	0.0	0.0	0.0
Total-N	28.4	7.6	11.4	12.6	22.2	1.6	8.5	12.5	8.3*	0.0*	2.3*	6.3*

* In 1977, TKN was measured instead of total-N

+ Flow weighted mean concentration (FWM)

TABLE 16. CONCENTRATION AND LOAD OF POLLUTANTS FROM ROHRS LENAWEE (301) SURFACE RUNOFF

	1975				1976				1977			
	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load
	High	Low	FWM+	(kg/ha)	High	Low	FWM	(kg/ha)	High	Low	FWM	(kg/ha)
Sediment	-[*]	-	-	-	2624[†]	2624	2624	686	435	69	361	204
Filtered reactive-P	-	-	-	-	0.16	0.16	0.16	0.04	1.18	0.15	0.97	0.55
Total-P	-	-	-	-	4.30	4.30	4.30	1.00	1.89	0.26	0.46	0.26
(Nitrate + nitrite)-N	-	-	-	-	4.6	4.6	4.6	1.1	13.6	1.1	10.4	5.9
Ammonia-N	-	-	-	-	0.6	0.6	0.6	0.1	4.1	0.0	2.3	0.5
Total-N	-	-	-	-	15.3	15.3	15.3	3.6	-[‡]	-	-	-

---

[*] There was no surface runoff from this site in 1975

[†] There was only one event in 1976

[‡] Missing data

TABLE 17. CONCENTRATION AND LOAD OF POLLUTANTS FROM ROHRS LENAWEE (9302) TILE DRAINAGE

	1975				1976				1977			
	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load
	High	Low	FWM+	(kg/ha)	High	Low	FWM	(kg/ha)	High	Low	FWM	(kg/ha)
Sediment	506	0	173	157	281	0	105	84	169	0	91	57
Filtered reactive-P	0.08	0.00	0.05	0.04	0.40	0.00	0.09	0.07	0.26	0.01	0.13	0.08
Total-P	8.10	0.00	0.93	0.84	1.85	0.00	0.31	0.24	1.68	0.21	0.71	0.44
(Nitrate + nitrite)-N	18.6	0.0	10.8	9.7	11.1	0.0	6.4	5.1	24.1	8.4	12.0	7.5
Ammonia-N	4.2	0.0	0.5	0.5	2.5	0.0	0.8	0.4	1.4	0.0	0.1	0.1
Total-N	13.0	4.0	9.7	8.2	11.9	3.3	8.7	7.0	10.2*	0.0*	6.7*	4.2*

* In 1977, TKN was measured instead of total-N

+ Flow weighted mean concentration (FWM)

TABLE 18. CONCENTRATION AND LOAD OF POLLUTANTS FROM HEISLER BLOUNT (401) SURFACE RUNOFF

	1975				1976				1977			
	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load
	High	Low	FWM+	(kg/ha)	High	Low	FWM	(kg/ha)	High	Low	FWM	(kg/ha)
Sediment	2927	489	2014	891	7866	54	2455	3421	2091	334	676	1055
Filtered reactive-P	0.18	0.01	0.09	0.04	0.40	0.00	0.07	0.08	0.03	0.00	0.02	0.02
Total-P	4.54	0.54	2.57	1.14	8.25	0.00	1.68	2.33	1.57	0.57	1.13	1.76
(Nitrate + nitrite)-N	7.0	0.0	4.4	1.8	7.1	0.0	3.1	4.3	20.0	6.2	11.6	18.1
Ammonia-N	7.1	0.0	2.2	1.0	8.3	0.0	1.1	1.1	0.0	0.0	0.0	0.0
Total-N	13.6	1.6	7.8	3.5	21.9	2.9	10.1	14.1	7.8*	1.5*	4.7*	7.3*

* In 1977, TKN was measured instead of total-N

+ Flow weighted mean concentration (FWM)

TABLE 19. CONCENTRATION AND LOAD OF POLLUTANTS FROM HEISLER BLOUNT (402) TILE

	1975				1976				1977			
	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load
	High	Low	FWM+	(kg/ha)	High	Low	FWM	(kg/ha)	High	Low	FWM	(kg/ha)
Sediment	1561	0	250	128	1365	0	240	245	422	0	130	107
Filtered reactive-P	0.26	0.00	0.05	0.03	0.45	0.00	0.07	0.08	0.06	0.00	0.04	0.03
Total-P	1.00	0.00	0.19	0.09	2.60	0.00	0.34	0.35	0.79	0.26	0.35	0.28
(Nitrate + nitrite)-N	19.6	0.00	12.5	6.4	32.8	0.0	8.4	8.6	24.9	7.1	12.2	10.1
Ammonia-N	14.3	0.0	1.1	0.6	2.8	0.0	0.1	0.1	1.5	0.0	0.2	0.1
Total-N	27.0	4.0	15.8	8.1	41.7	1.6	10.0	10.2	20.8*	0.0*	5.7*	4.7*

---

* In 1977, TKN was measured instead of total-N

+ Flow weighted mean concentration (FWM)

TABLE 20. CONCENTRATION AND LOAD OF POLLUTANTS FROM PAULDING (501) SURFACE RUNOFF

	1975				1976				1977			
	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load
	High	Low	FWM+	(kg/ha)	High	Low	FWM	(kg/ha)	High	Low	FWM	(kg/ha)
Sediment	15927	230	2590	4576	7263	114	2131	4434	7888	372	1098	3849
Filtered reactive-P	0.09	0.01	0.07	0.13	0.30	0.01	0.12	0.25	0.63	0.00	0.29	1.02
Total-P	6.16	0.20	1.14	1.97	4.75	0.45	1.93	4.02	8.18	1.47	1.97	6.89
(Nitrate + nitrite)-N	8.8	0.0	3.6	6.3	6.6	0.0	2.6	5.5	14.1	1.1	4.1	14.3
Ammonia-N	3.2	0.0	0.7	1.1	2.4	0.0	0.8	1.6	1.4	0.0	1.3	1.6
Total-N	28.7	4.1	11.6	20.4	19.5	2.0	8.4	17.5	14.9*	2.6*	3.5*	12.3*

---

* In 1977, TKN was measured instead of total-N

+ Flow weighted mean concentration (FWM)

TABLE 21. CONCENTRATION AND LOAD OF POLLUTANTS FROM PAULDING (502) TILE DRAINAGE

	1975				1976				1977			
	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load
	High	Low	FWM+	(kg/ha)	High	Low	FWM	(kg/ha)	High	Low	FWM	(kg/ha)
Sediment	2583	0	1192	100	607	0	353	89	-*	-	-	-
Filtered reactive-P	0.35	0.01	0.08	0.01	0.22	0.00	0.03	0.01	-	-	-	-
Total-P	5.28	0.00	1.54	0.11	0.90	0.00	0.31	0.08	-	-	-	-
(Nitrate + nitrite)-N	9.7	0.0	5.3	0.4	42.6	0.0	32.5	8.2	-	-	-	-
Ammonia-N	12.0	0.0	1.1	0.1	2.8	0.0	0.3	0.1	-	-	-	-
Total-N	16.4	5.7	10.5	0.8	45.4	4.1	35.7	9.0	-	-	-	-

---

* There were no events in 1977.

TABLE 22. CONCENTRATION AND LOAD OF POLLUTANTS FROM HOYTVILLE PLOTS (6 x 1) SURFACE RUNOFF (MEAN OF ALL EIGHT PLOTS)

	1975				1976				1977			
	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load
	High	Low	WM+	(kg/ha)	High	Low	FWM	(kg/ha)	High	Low	FWM	(kg/ha)
Sediment	14180	0	1891	744	3832	0	105	58	8632	0	235	218
Filtered reactive-P	3.92	0.00	0.31	0.01	1.79	0.00	0.32	0.17	9.02	0.00	0.66	0.63
Total-P	5.85	0.00	0.82	0.16	5.85	0.00	0.56	0.30	9.18	0.00	1.12	1.10
(Nitrate + nitrite)-N	13.7	0.0	2.9	1.2	13.2	0.0	1.2	0.6	29.4	0.0	4.0	4.2
Ammonia-N	9.5	0.0	1.5	0.6	16.4	0.0	0.6	0.3	7.0	0.0	0.3	0.2
Total-N	64.0	0.0	6.6	2.4	71.0	0.0	3.0	1.5	19.7*	0.0*	1.0*	0.8*

* In 1977, TKN was measured instead of total-N

+ Flow weighted mean concentration (FWM)

TABLE 23. CONCENTRATION AND LOAD OF POLLUTANTS FROM HOYTVILLE PLOTS (6 x 2) TILE DRAINAGE

	1975				1976				1977			
	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load	Concentration (ug/ml)			Load
	High	Low	FWM+	(kg/ha)	High	Low	FWM	(kg/ha)	High	Low	FWM	(kg/ha)
Sediment	1769	0	136	241	197	0	14	28	4408	0	26	50
Filtered reactive-P	0.88	0.00	0.07	0.13	0.66	0.00	0.05	0.09	5.01	0.00	0.09	0.23
Total-P	3.86	0.00	0.27	0.11	8.05	0.00	0.20	0.40	5.56	0.00	0.32	0.73
(Nitrate + nitrite)-N	17.6	0.00	7.5	15.3	19.5	0.0	5.1	10.6	21.7	0.0	8.7	20.5
Ammonia-N	16.6	0.00	2.8	5.2	3.5	0.0	0.3	0.5	2.1	0.0	0.1	0.2
Total-N	16.9	0.0	8.6	17.5	16.2	0.0	5.8	11.9	10.9*	0.0*	1.2*	2.3*

---

* In 1977, TKN was measured instead of total-N

+ Flow weighted mean concentration (FWM)

Nitrogen - None of the sites received any nitrogen fertilizer during the study period, since soybeans were grown in all cases. In all cases, most of the nitrogen loss was as NO_3-N. Ammonia-N loss was low and organic-N (sediment-N) was only significant at the higher soil loss levels. Nitrate-N losses were similar to amounts added to soil in precipitation ($\sim$ 15 kgN/ha/yr).

4.42 Overview of Watershed Loadings

Figures 23-26 give hydrographs for the Maumee and Portage Rivers and one of the Black Creek Watersheds. The flashier nature of the Black Creek watershed is due to its smaller drainage area and higher percentage of sloping soils.

Table 24 presents the total (all pollution sources) annual sediment and nutrient loading and unit area yields for all study watersheds in the Maumee and Portage River basins, including the Black Creek watershed sub-basin and the experimental plots in Defiance and Wood Counties, Ohio. The loading for the Maumee does not include any of the point or diffuse loading from the City of Toledo or the drainage below the gauging station at Waterville.

Tables 25 through 28 present the monthly loading rates (metric tons/day) during each month of the study periods on the Maumee, Portage, and the two Black Creek Watershed sub-basins. The figures presented in these tables are the results of the application of the Beale Ratio Estimator method of calculation to the chemical measurements and continuous flow records at each of the sampling sites.

Tables 29 and 30 present the total monthly and annual loads, flow weighted mean concentrations, and monthly and annual total transport unit area yields for the Maumee and Portage River basins. Also presented, in the last three columns of each table, are the mean daily flow, basinwide runoff, and mean basinwide precipitation for each month of the study period.

Table 31 presents the monthly and annual total chloride loading for 1975 and 1976 for the Maumee and Portage River basins. The unit yields of chloride for 1975 and 1976 were for the Maumee 127 and 77 kg/ha/yr, and for the Portage 138 and 100 kg/ha/yr. These yields are at the high extreme of chloride loadings for general agriculture and at the low extreme of general urban land use as observed in other Task C pilot watershed studies. The loadings appear to be directly related to flow and do not appear to be drastically reduced in the low flow relative to the high flow months. Certainly much of the chloride orginates as a result of road deicing operations. The lesser reduction in the Portage River relative to the Maumee in the low flow year, 1976, is probably a result of a higher degree of urbanization and larger percentage of point source inputs into that basin. The City of Bowling Green is not located within the watershed but does discharge its sewage treatment plant and a considerable portion of its urban runoff to the Portage rather than the Maumee.

FIGURE 23. FLOW HYDROGRAPHS FOR MAUMEE RIVER AT WATERVILLE, 1975

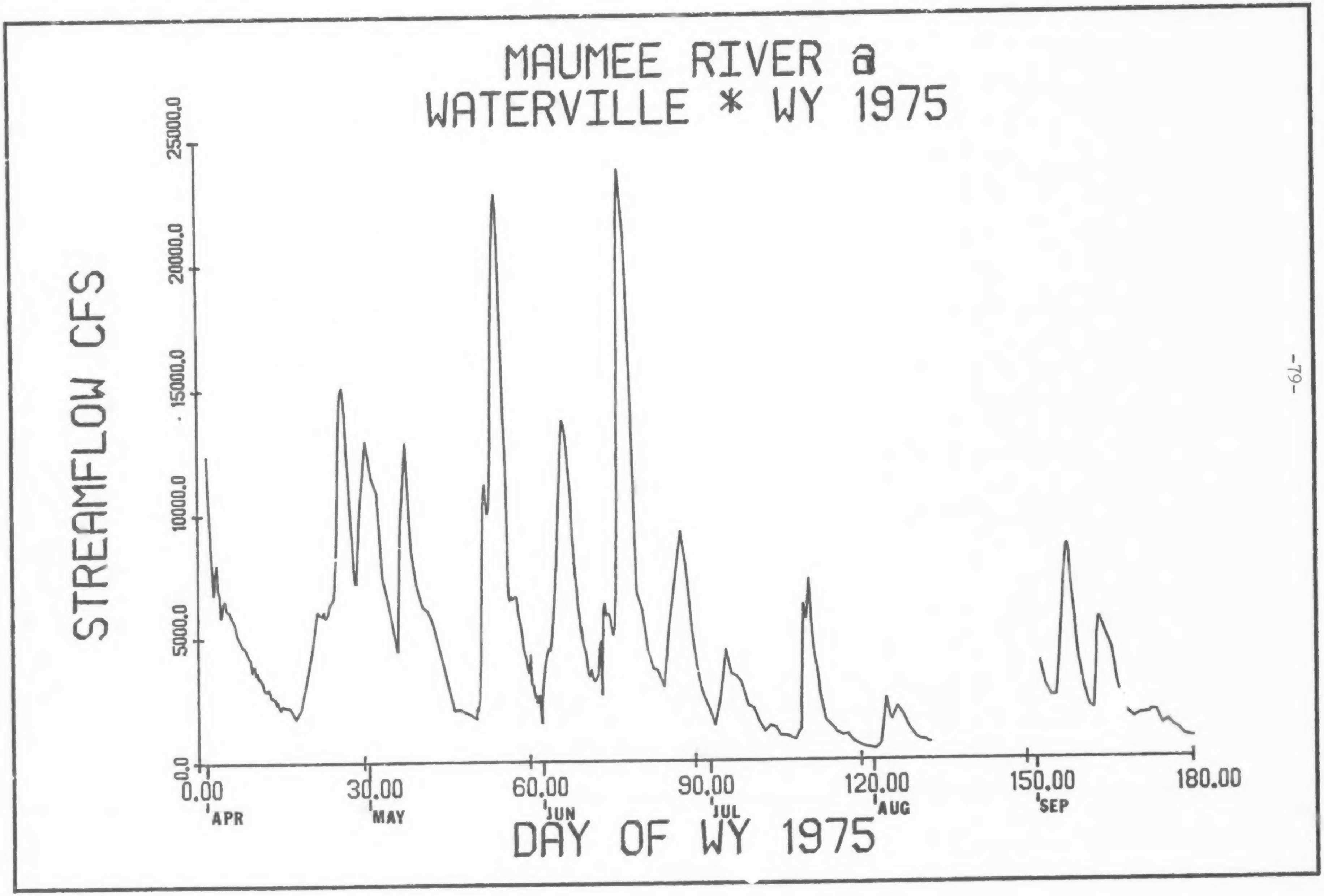

FIGURE 24. FLOW HYDROGRAPHS FOR MAUMEE RIVER AT WATERVILLE, 1976

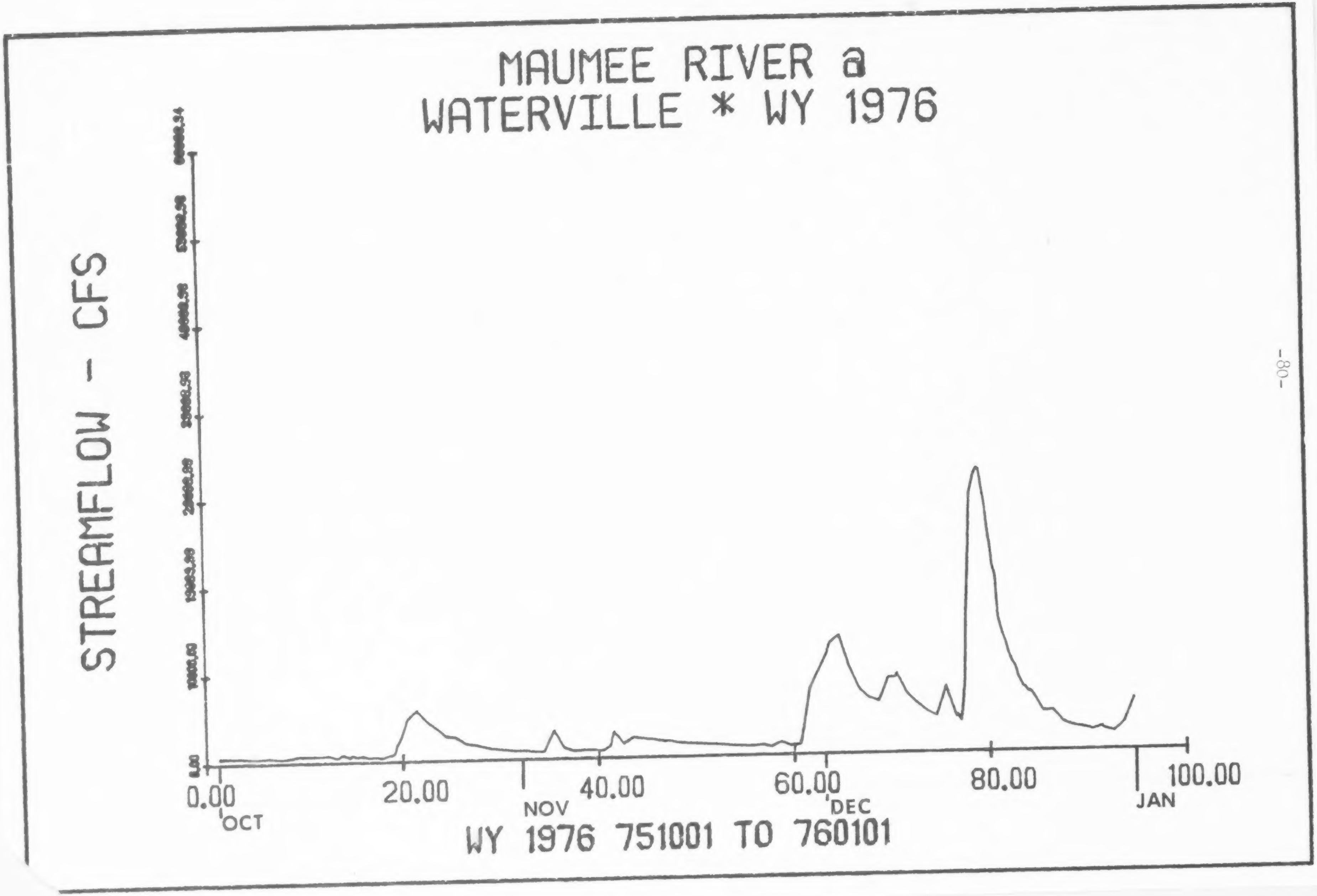

FIGURE 25. FLOW HYDROGRAPHS FOR PORTAGE RIVER AT WOODVILLE, 1976

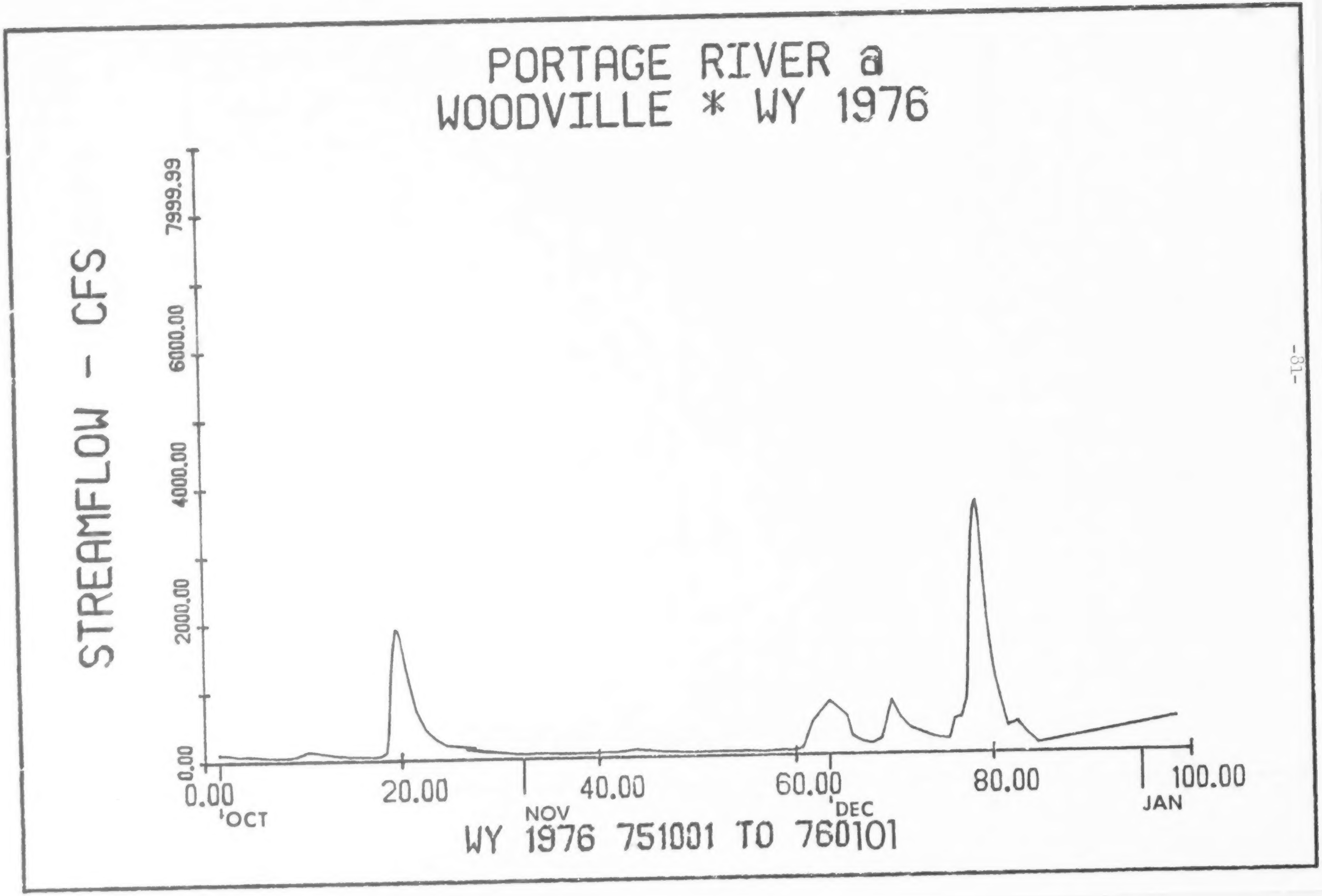

FIGURE 26. FLOW HYDROGRAPHS FOR BLACK CREEK, SITE 2, 1975

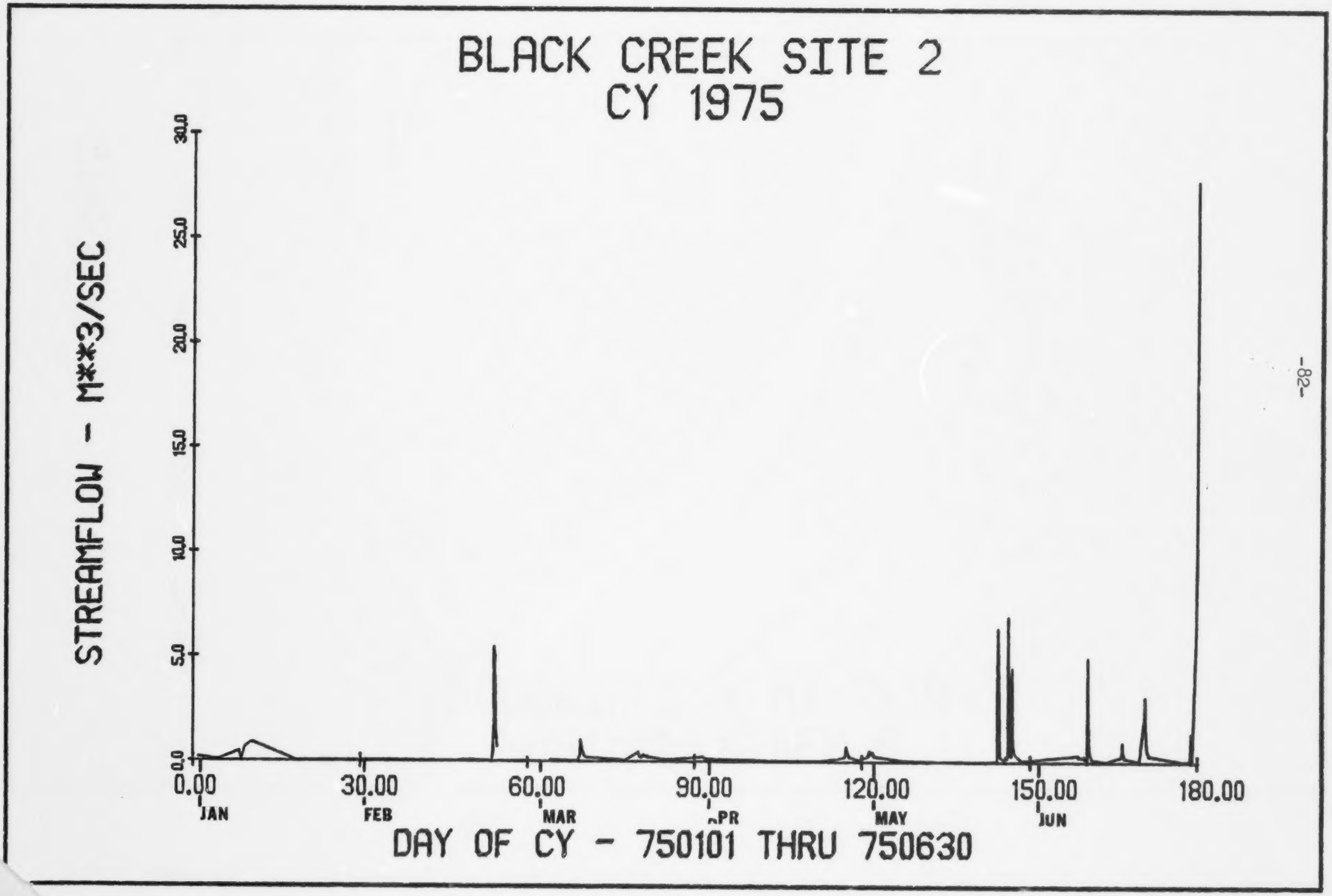

TABLE 24. TOTAL AND UNIT AREA LOADS FOR WATERSHEDS IN MAUMEE AND PORTAGE RIVER BASINS

WATERSHED	YEAR	DISSOLVED PHOSPHORUS TOTAL LOAD (MT/YR)	DISSOLVED PHOSPHORUS YIELD (KG/HA/YR)	TOTAL PHOSPHORUS (MT/YR)	TOTAL PHOSPHORUS (KG/HA/YR)	SEDIMENT (MT/YR)	SEDIMENT (KG/HA/YR)	(NITRATE-NITRITE)N (MT/YR)	(NITRATE-NITRITE)N (KG/HA/YR)	DRAINAGE AREA (SURFACE) (HA)
MAUMEE	1975	561.	0.342	3,440.	2.10	1,609,989.	982.	31,864.	19.3	
	1976	399.	0.243	2,505.	1.53	1,509,105.	920.	12,207.	7.4	1,639,500.
PORTAGE	1975	39.3	0.35	160.6	1.45	105,251.	949.1	2,167.	19.5	110,900.
	1976	26.4	0.24	92.5	0.83	40,727.	367.2	739.	6.66	
Black Creek Site 2	1975	0.188	0.199	6.2	6.60	2,864.	3,040.	15.8	16.82	942.
	1976	0.070	0.075	0.70	0.72	237.	251.	3.4	3.62	
Black Creek Site 6	1975	0.123	0.173	3.7	5.06	2,800.	3,922.	5.1	7.06	714.
	1976	0.085	0.119	0.40	0.619	208.	291.	1.0	1.46	
PLOT 111 (Roselms)	1975	1.92(-4)*	0.06	2.9(-3)	0.92	5.71	1783.	7.2(-3)	2.24	3.2
	1976	6.40(-4)	0.20	7.8(-3)	2.43	11.87	3710.	7.2(-2)	22.41	
PLOT 201 (Roselms)	1975	6.50(-5)	0.11	9.2(-4)	1.54	3.05	5083.	3.3(-3)	5.52	0.6
	1976	6.50(-5)	0.11	1.1(-3)	1.79	1.38	2293.	4.9(-3)	8.22	
PLOT 301 + 302 (Lenawee)	1975	4.0(-5)	0.05	7.5(-4)	0.94	0.125	156.	8.7(-3)	10.88	0.8
	1976	9.6(-5)	0.12	2.2(-4)	0.27	0.614	768.	4.6(-3)	5.77	
PLOT 401 + 402 (Blount)	1975	7.2(-5)	0.08	1.3(-3)	1.40	0.914	1016.	8.3(-3)	9.25	0.9
	1976	1.53(-4)	0.17	3.0(-3)	3.38	3.29	3661.	1.3(-2)	14.49	
PLOT 501 + 502 (Paulding)	1975	1.5(-4)	0.15	2.3(-3)	2.33	4.67	4672	7.5(-3)	7.50	1.0
	1976	2.9(-4)	0.29	4.6(-3)	4.58	4.52	4518	1.5(-2)	15.37	
PLOTS 611 to 682 (Hoytville) (Mean of all plots)	1975	1.2(-5)	0.29	-	-	4.8(-2)	1192.	7.4(-4)	18.59	0.04
	1976	1.2(-5)	0.29	3.2(-5)	0.81	3.3(-3)	82.	5.2(-4)	13.08	

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*$1.92(-4) = 1.92 \times 10^{-4}$

TABLE 25. MONTHLY LOADINGS, MAUMEE RIVER AT WATERVILLE

		DISSOLVED PHOSPHORUS		TOTAL PHOSPHORUS		SUSPENDED SEDIMENT		NITRATE+NITRITE - N		AMMONIA - N	
		MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR
1975	JAN*	2.0		23.9		11546.		187.		5.82	
	FEB*	3.50		27.1		9967.		188.		6.93	
	MAR*	2.74		8.62		2102.		106.		6.44	
	APR	1.354	0.038	4.81	0.184	2167.1	160.2	110.8	2.05	2.057	0.259
	MAY	1.784	0.081	11.60	1.01	6012.7	808.6	134.2	5.44	2.185	0.550
	JUN	2.074	0.038	8.86	0.994	5425.5	760.2	148.2	3.17	1.087	0.194
	JUL	0.483	0.066	1.95	0.085	1189.0	83.9	16.6	1.88	0.669	0.975
	AUG	0.247	0.021	0.777	0.027	325.9	17.2	4.57	0.128	0.425	0.104
	SEP	1.178	0.020	3.46	0.089	1012.9	70.0	15.0	0.162	1.320	0.099
	OCT	0.318	0.028	1.11	0.046	304.9	9.82	9.03	0.443	0.798	0.062
	NOV	0.314	0.050	1.17	0.172	153.9	14.0	7.49	0.556	0.348	0.066
	DEC	2.604	0.074	20.84	2.41	12975.6	2215.7	122.4	1.88	2.622	0.155
	YEAR										
1976	JAN	1.851	0.040	3.69	0.196	387.6	58.7	35.7	1.90	6.886	0.393
	FEB	8.246	0.702	52.49	2.51	34790.8	3101.9	232.3	21.15	19.08	1.51
	MAR	1.392	0.035	21.33	1.51	13526.2	1411.3	39.5	7.37	3.044	0.252
	APR	0.407	0.031	1.18	0.084	475.2	45.6	21.6	1.92	1.403	0.358
	MAY	0.543	0.064	2.308	0.149	850.5	75.2	39.9	1.66	0.898	0.247
	JUN	0.359	0.019	1.295	0.026	453.1	12.8	29.4	1.50	0.683	0.054
	JUL	0.245	0.024	0.748	0.023	236.2	6.26	8.90	0.510	0.315	0.032
	AUG	0.100	0.007	0.285	0.010	78.9	3.63	0.819	0.076	0.197	0.031
	SEP	0.106	0.002	0.235	0.004	49.6	1.93	0.075	0.008	0.078	0.006
	OCT	0.078	0.014	0.330	0.024	80.3	26.6	0.110	0.039	0.131	0.017
	NOV	0.026	0.004	0.128	0.004	11.6	0.82	0.441	0.041	0.134	0.018
	DEC	0.088	0.009	0.279	0.008	17.3	1.64	1.61	0.168	0.248	0.029
	YEAR										

TABLE 25. (CONTINUED)

		DISSOLVED PHOSPHORUS		TOTAL PHOSPHORUS		SUSPENDED SEDIMENT		NITRATE+NITRITE - N		AMMONIA - N	
		MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR
1977	JAN	0.120	0.022	0.166	0.015	2.43	0.65	0.938	0.074	0.487	0.143
	FEB	1.396	0.097	1.984	0.146	50.90	80.41	6.87	1.53	7.79	1.22
	MAR	3.173	0.122	24.05	3.35	12194.1	1959.2	243.3	7.26	13.37	0.766
	APR	2.689	0.078	31.35	6.68	18730.7	4538.2	234.8	4.02	3.59	0.552
	MAY	0.952	0.020	6.15.	0.37	3064.2	271.6	92.5	1.38	2.58	1.50
	JUN	0.202	0.009	0.559	0.025	159.0	8.05	3.64	1.38	0.291	0.028
	JUL										
	AUG										
	SEP										
	OCT										
	NOV										
	DEC										
	YEAR										

TABLE 26. MONTHLY LOADINGS, PORTAGE RIVER AT WOODVILLE

		DISSOLVED PHOSPHORUS		TOTAL PHOSPHORUS		SUSPENDED SEDIMENT		NITRATE+NITRITE - N		AMMONIA - N	
		MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR
1975	JAN	0.178	0.013	0.885	0.063	450.5	58.9	12.94	0.319	0.298	0.066
	FEB	0.241	0.019	1.13	0.088	546.6	72.8	20.61	0.340	0.388	0.052
	MAR	0.129	0.015	0.236	0.015	63.9	10.6	5.57	0.404	0.159	0.039
	APR	0.071	0.005	0.101	0.008	9.04	0.92	2.93	0.136	0.036	0.004
	MAY	0.158	0.014	1.181	0.122	1022.4	161.6	12.48	0.650	0.227	0.026
	JUN	0.120	0.010	0.291	0.016	129.0	17.5	6.14	0.504	0.100	0.029
	JUL	0.024	0.002	0.044	0.004	6.67	0.97				
	AUG	0.016	0.001	0.027	0.003	4.07	0.27	0.091	0.016	0.010	0.001
	SEP	0.172	0.007	0.330	0.016	836.5	305.2	2.32	0.121	0.112	0.019
	OCT	0.045	0.003	0.138	0.024	30.4	6.83	1.71	0.100	0.044	0.005
	NOV	0.015	0.003	0.051	0.017	2.61	1.30	0.31	0.12	0.017	0.002
	DEC	0.135	0.007	0.909	0.142	421.7	92.5	7.18	0.42	0.159	0.017
	YEAR										
1976	JAN	0.198	0.005	0.413	0.030	101.7	16.8	3.45	0.23	0.616	0.030
	FEB	0.495	0.044	2.316	0.168	1185.9	200.6	14.52	1.00	0.824	0.031
	MAR	0.023	0.001	0.077	0.009	26.6	5.79	1.35	0.060	0.058	0.017
	APR	0.026	0.002	0.051	0.002	5.18	0.38	0.99	0.44	0.051	0.007
	MAY	0.050	0.004	0.155	0.029	75.2	30.9	3.60	0.416	0.058	0.011
	JUN	0.019	0.001	0.048	0.005	13.2	4.05	0.862	0.104	0.028	0.004
	JUL	0.017	0.001	0.036	0.001	7.17	0.43	0.072	0.014	0.012	0.001
	AUG	0.014	0.001	0.026	0.002	5.68	1.28	0.084	0.010	0.012	0.001
	SEP	0.008	0.0003	0.027	0.002	7.25	0.72	0.048	0.004	0.009	0.001
	OCT	0.006	0.001	0.008	0.001	0.47	0.089	0.047	0.006	0.002	0.0004
	NOV	0.012	0.001	0.016	0.001	0.26	0.036	0.153	0.011	0.008	0.002
	DEC	0.035	0.002	0.043	0.002	0.724	0.353	0.171	0.006	0.106	0.005
	YEAR										

TABLE 26. (CONTINUED)

		DISSOLVED PHOSPHORUS		TOTAL PHOSPHORUS		SUSPENDED SEDIMENT		NITRATE+NITRITE - N		AMMONIA - N	
		MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR
1977	JAN	0.138	0.006	0.187	0.009	1.85	0.23	0.057	0.010	0.305	0.0001
	FEB	0.508	0.004	0.792	0.014	66.3	21.2	0.527	0.046	1.571	0.241
	MAR	0.315	0.013	1.123	0.101	502.5	78.9	26.64	0.56	0.690	0.067
	APR	0.188	0.006	0.601	0.036	153.4	18.0	18.25	1.20	0.380	0.049
	MAY	0.085	0.002	0.250	0.023	70.8	13.9	5.99	0.18	0.057	0.025
	JUN	0.025	0.001	0.042	0.002	1.21	0.050	0.067	0.007	0.010	0.001
	JUL										
	AUG										
	SEP										
	OCT										
	NOV										
	DEC										
	YEAR										

TABLE 27. MONTHLY LOADINGS, BLACK CREEK, SITE 2

	DISSOLVED PHOSPHORUS		TOTAL PHOSPHORUS		SUSPENDED SEDIMENT		NITRATE+NITRITE - N		AMMONIA - N	
	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR ±(MT/DAY)	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR ±(MT/DAY)	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR
1975 JAN	0.0111	0.0004	0.0073	0.0026	3.84	1.85	0.030	0.012	0.0072	0.0022
FEB	0.0013	0.0004	0.012	0.0063	7.79	4.77	0.023	0.0087	0.0066	0.0022
MAR	0.0012	0.0002	0.0041	0.0004	2.12	0.29	0.033	0.0022	0.0038	0.0003
APR	0.0011	0.00003	0.0035	0.0008	1.70	0.48	0.027	0.0017	0.0034	0.0007
MAY	0.0011	0.0001	0.035	0.0086	36.57	13.82	0.026	0.011	0.0039	0.0014
JUN	0.0008	0.0001	0.034	0.0042	36.75	8.35	0.025	0.0007	0.0020	0.0003
JUL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AUG	0.0003	<0.00005	0.0014	0.0001	0.423	0.015	0.0009	0.0001	0.0006	<0.00005
SEP	0.0003	<0.00005	0.0035	0.0005	0.788	0.145	0.0017	0.0002	0.0006	0.0001
OCT	0.0	0.0	0.0001	<0.00005	0.021	0.003	0.0001	0.0001	0.0001	<0.00005
NOV	0.0008	<0.00005	0.0042	0.0005	1.02	0.073	0.0082	0.0002	0.0014	0.0002
DEC	0.0007	0.0001	0.0229	0.0042	1.86	0.20	0.014	0.001	0.0018	0.0012
YEAR										
1976 JAN	0.002	<0.00005	0.0005	<0.00005	0.161	0.009	0.0022	0.0003	0.0027	0.0006
FEB	0.0030	0.0002	0.0125	0.0009	4.85	0.73	0.024	0.0011	0.0088	0.0004
MAR	0.0009	0.0003	0.0043	0.0006	2.07	0.22	0.016	0.0031	0.0019	0.0012
APR	0.0001	<0.00005	0.0003	0.0001	0.114	0.0042	0.0003	0.0006	0.0004	<0.00005
MAY	0.0001	<0.00005	0.0002	<0.00005	0.075	0.007	0.0007	0.0004	0.0004	0.0001
JUN	0.0001	<0.00005	0.0001	<0.00005	0.041	0.0003	0.0001	0.0001	0.0001	<0.00005
JUL	0.0	0.0	0.001	<0.00005	0.0093	0.0011	0.0	0.0	0.0	0.0
AUG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OCT	0.001	<0.00005	0.0001	<0.00005	0.038	0.0014	0.0005	0.0001	0.0005	0.0001
NOV	0.0002	<0.00005	0.0002	<0.00005	0.043	0.017	0.0006	0.0001	0.0016	0.0002
DEC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YEAR										

TABLE 28. MONTHLY LOADINGS, BLACK CREEK, SITE 6

		DISSOLVED PHOSPHORUS		TOTAL PHOSPHORUS		SUSPENDED SEDIMENT		NITRATE+NITRITE - N		AMMONIA - N	
		MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY)	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR	MEAN DAILY LOAD (MT/DAY	STANDARD ERROR
1975	JAN	0.0011	0.0001	0.0062	0.0012	3.10	1.01	0.108	0.028	0.0048	0.001
	FEB	0.0009	0.0001	0.021	0.004	6.40	0.58	0.089	0.006	0.0083	0.0013
	MAR	0.004	>0.00005	0.0022	0.0002	1.51	0.15	0.067	0.005	0.0039	0.0005
	APR	0.0005	0.0001	0.0017	0.0002	1.03	0.216	0.051	0.006	0.0052	0.0010
	MAY	0.0014	0.0001	0.077	0.008	47.7	10.1	0.046	0.006	0.016	0.007
	JUN	0.0015	0.0001	0.060	0.0097	25.5	4.00	0.098	0.009	0.005	0.0008
	JUL	0.0001	<0.00005	0.0018	0.0002	1.17	0.19	0.0043	0.0008	0.0004	0.0001
	AUG	0.0001	-	0.0002	0.0001	0.13	0.039	0.0008	0.0004	0.0001	-
	SEP	0.0001	>0.00005	0.0007	0.0002	0.41	0.28	0.0035	0.0005	0.0005	0.0002
	OCT	0.0	<0.00005	0.0001	<0.00005	0.072	0.0055	0.0003	<0.0000'	0.0001	<0.00005
	NOV	0.0004	0.0001	0.0051	0.0018	1.06	0.18	0.012	0.002	0.002	0.0004
	DEC	0.0008	0.0001	0.031	0.006	5.93	1.28	0.051	0.006	0.0027	0.0003
	YEAR										
1976	JAN	0.0	-	0.0003	<0.00005	0.215	0.009	0.0053	0.0004	0.0015	0.0004
	FEB	0.0021	0.0001	0.020	0.0011	5.87	0.54	0.051	0.001	0.007	0.0003
	MAR	0.0004	0.0001	0.0025	0.0005	1.30	0.099	0.028	0.0008	0.002	0.001
	APR	0.0002	<0.00005	0.0011	0.0001	0.48	0.028	0.025	0.0009	0.003	0.0002
	MAY	0.0	0.0	0.0001	<0.00005	0.139	0.005	0.0063	0.0004	0.0002	-
	JUN	0.0	0.0	0.0	0.0	0.49	0.006	0.0014	0.0003	0.0	0.0
	JUL	0.0	0.0	0.0001	<0.00005	0.021	0.0022	0.0	0.0	0.0001	0.0
	AUG	0.0	0.0	0.0	0.0	0.016	0.004	0.0001	0.0001	0.0001	0.0001
	SEP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	OCT	0.0	0.0	0.0001	<0.00005	0.030	0.002	0.0000	0.0001	0.0001	<0.00005
	NOV	0.0	0.0	0.0	0.0	0.0082	<0.00005	0.0	0.0	0.0	0.0
	DEC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 29. MONTHLY LOAD, UNIT AREA YIELD, FLOW WEIGHTED MEAN CONCENTRATION FLOW AND PRECIPITATION, MAUMEE RIVER AT WATERVILLE

		DISSOLVED INORGANIC PHOSPHORUS			TOTAL PHOSPHORUS			SUSPENDED SEDIMENT		
		TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)	TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)	TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)
1975	JAN	62.0	0.087	0.038	740.9	1.044	0.452	357926.	504.3	218.3
	FEB	98.0	0.106	0.060	758.8	0.824	0.463	279076.	303.2	170.2
	MAR	84.9	0.141	0.052	267.2	0.445	0.163	65131.	108.4	39.7
	APR	40.6	0.090	0.025	144.4	0.321	0.088	65015.	144.4	39.6
	MAY	55.3	0.103	0.033	359.6	0.670	0.219	186393.	347.1	113.7
	JUN	62.2	0.116	0.038	265.9	0.497	0.162	162766.	304.3	99.3
	JUL	15.0	0.093	0.009	60.4	0.376	0.037	36858.	229.6	22.5
	AUG	7.7	0.046	0.005	24.1	0.144	0.015	10104.	60.3	6.2
	SEP	35.3	0.160	0.022	103.8	0.471	0.063	30387.	137.9	18.5
	OCT	9.9	0.089	0.006	34.4	0.308	0.021	9452.	84.6	5.8
	NOV	9.4	0.084	0.006	35.0	0.313	0.021	4617.	41.3	2.8
	DEC	80.7	0.129	0.049	645.9	1.03	0.394	402228.		245.9
	YEAR	561.0		0.342	3440.4		2.10	1609989.		982.
1976	JAN	57.4	0.155	0.035	114.5	0.309	0.070	12016.	32.4	7.3
	FEB	239.1	0.117	0.146	1522.3	0.744	0.929	1008933.	493.2	615.4
	MAR	43.1	0.045	0.026	661.3	.684	0.403	419313.	433.7	255.8
	APR	12.2	0.055	0.007	35.[illegible]	0.160	0.022	14256.	64.5	8.7
	MAY	16.3	0.079	0.010	71.5	0.338	0.044	26367.	124.6	16.1
	JUN	10.8	0.082	0.007	38.8	0.297	0.024	13592.	103.8	8.3
	JUL	7.6	0.094	0.005	23.2	0.287	0.287	7321.	90.7	4.5
	AUG	3.1	0.076	0.002	8.8	0.216	0.005	2445.	59.9	1.5
	SEP	3.2	0.152	0.002	7.0	0.335	0.004	1488.	70.7	0.9
	OCT	2.5	0.064	0.002	10.2	0.265	0.006	2491.	64.5	1.5
	NOV	0.79	0.030	0.0005	3.8	0.146	0.002	347.	13.3	0.2
	DEC	2.8	0.072	0.002	8.6	0.227	0.005	536.	14.1	0.3
	YEAR	399.4		0.243	2505.3		1.53	1509105.		920.
1977	JAN	3.7	0.154	0.002	4.8	0.199	0.003	75.3	3.1	0.0
	FEB	38.8	0.358	0.024	55.6	0.513	0.034	1425.	13.4	0.9
	MAR	98.4	0.094	0.060	724.9	0.692	0.442	378018.	360.8	230.6
	APR	80.7	0.093	0.049	940.4	1.082	0.573	561919.	646.3	342.7
	MAY	29.5	0.082	0.018	190.5	0.528	0.116	94992.	263.2	57.9
	JUN	6.1	0.127	0.004	16.8	0.350	0.010	4771.	99.6	2.9
	YEAR									

TABLE 29. (CONTINUED)

NITRATE+NITRITE-N			AMMONIA-N			MEAN DAILY FLOW (M**3/S)	RUNOFF (cm)	TOTAL PRECIPITATION (cm)
TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)	TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)			
5797.	8.17	3.54	180.4	0.254	0.110	266.2	4.34	6.48
5264.	4.72	3.21	194.0	0.211	0.118	382.0	5.64	6.40
3286.	5.47	2.00	199.6	0.332	0.122	225.3	3.68	5.60
3326..	7.39	2.03	61.7	0.137	0.038	174.6	2.77	7.01
4160.	7.75	2.54	67.7	0.126	0.041	201.4	3.30	9.32
4447.	8.31	2.71	32.6	0.061	0.020	207.3	3.28	12.40
515.	3.21	0.31	20.7	0.129	0.013	60.2	0.99	9.86
142.	0.85	0.09	13.2	0.079	0.008	62.8	1.04	15.60
449.	2.04	0.27	39.6	0.180	0.024	85.4	1.35	6.90
280.	2.51	0.171	24.7	0.221	0.015	41.9	0.69	5.22
225.	2.01	0.137	10.4	0.093	0.006	43.3	0.69	6.35
3793	6.06	2.31	81.3	0.130	0.050	234.7	3.84	6.34
31684.		19.3	925.9		0.564	151.0	31.59	97.52
1107	2.99	0.68	213.5	0.576	0.130	139.0	2.26	6.44
6737	3.29	4.11	553.4	0.271	0.338	849.6	12.98	7.32
1224.	1.27	0.75	94.4	0.098	0.058	362.8	5.92	8.06
647.	2.93	0.40	42.1	0.190	0.026	85.7	1.35	5.39
1239	5.85	0.76	27.8	0.131	0.017	79.4	1.30	6.57
883.	6.74	0.54	20.5	0.156	0.013	50.8	0.81	8.83
276.	3.42	0.169	9.8	0.121	0.006	30.3	0.48	7.90
25.4	0.63	0.016	6.1	0.150	0.004	15.3	0.25	4.34
2.3	0.107	0.001	2.3	0.111	0.001	8.16	0.13	6.64
3.4	0.088	0.002	4.1	0.105	0.003	14.5	0.73	8.28
13.2	0.507	0.008	3.4	0.130	0.002	10.1	0.51	1.44
49.8	1.31	0.030	7.7	0.203	0.005	14.3	0.72	2.07
12207.		7.44	985.1		0.601	159.2	27.44	71.26
29.1	1.21	0.02	15.1	0.627	0.009	9.03	0.14	
192.3	1.77	0.12	218.2	2.01	0.133	45.0	0.66	
7511.0	7.20	4.60	414.4	0.395	0.253	393.1	6.39	
7043.	8.10	4.30	107.7	0.124	0.066	337.0	5.30	
2867.	7.94	1.75	80.0	0.222	0.049	135.3	2.20	
109.2	2.28	0.07	8.7	0.182	0.005	18.6	0.29	
						54.8	2.34	

TABLE 30. MONTHLY LOAD, UNIT AREA YIELD, FLOW WEIGHTED MEAN CONCENTRATION, FLOW AND PRECIPITATION, PORTAGE RIVER AT WOODVILLE

		DISSOLVED INORGANIC PHOSPHORUS			TOTAL PHOSPHORUS			SUSPENDED SEDIMENT		
		TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)	TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)	TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)
1975	JAN	5.5	0.117	0.050	27.4	0.580	0.247	13965.	295.4	125.9
	FEB	6.8	0.118	0.061	31.6	0.554	0.285	14744	258.3	132.9
	MAR	3.9	0.145	0.035	7.1	0.265	0.064	1917	71.4	17.3
	APR	2.2	0.170	0.020	3.1	0.243	0.028	280.3	21.6	2.5
	MAY	4.9	0.114	0.044	36.6	0.854	0.330	31693.	739.5	285.8
	JUN	3.6	0.211	0.032	8.7	0.512	0.078	3869	227.0	34.9
	JUL	0.75	0.246	0.007	1.4	0.448	0.013	206.7	67.4	1.9
	AUG	0.48	0.026	0.004	0.83	0.045	0.007	126.3	6.8	1.1
	SEP	5.1	0.153	0.046	9.9	0.294	0.089	25096.	745.6	226.3
	OCT	1.4	0.098	0.013	4.3	0.299	0.039	211.8	66.0	1.9
	NOV	0.45	0.093	0.004	1.5	0.309	0.014	78.4	16.2	0.7
	DEC	4.2	0.100	0.038	28.2	0.737	0.254	12793.	335.	115.4
	YEAR	39.3		0.354	160.6		1.45	105251.		949.1
1976	JAN	6.1	0.128	0.055	12.8	0.267	0.115	3154.	65.8	28.4
	FEB	13.8	0.109	0.124	64.8	0.512	0.584	33204.	262.	299.4
	MAR	0.7	0.014	0.006	2.4	0.048	0.022	825.3	16.4	7.4
	APR	0.8	0.054	0.007	1.5	0.105	0.014	155.3	10.7	1.4
	MAY	1.6	0.112	0.014	4.8	0.349	0.043	2332.	[illegible]	21.0
	JUN	0.6	0.128	0.005	1.4	0.327	0.013	395.5	89.4	3.6
	JUL	0.52	0.170	0.005	1.11	0.362	0.010	222.4	72.5	2.0
	AUG	0.43	0.158	0.004	0.80	0.294	0.007	176.0	64.7	1.6
	SEP	0.23	0.159	0.002	0.81	0.558	0.007	217.6	149.9	2.0
	OCT	0.18	0.156	0.002	0.24	0.207	0.002	14.5	12.5	0.1
	NOV	0.37	0.277		0.47	0.353		7.8	5.9	
	DEC	1.09	0.564	0.010	1.34	0.691	0.012	22.5	11.6	0.2
	YEAR	26.4		0.238	92.5		0.834	40727.	367.2	
1977	JAN	4.27	0.913	0.039	5.80	1.24	0.052	57.4	12.3	0.5
	FEB	14.2	0.760	0.128	22.2	1.19	0.200	1855.9	99.1	10.7
	MAR	9.77	0.109	0.088	34.8	0.389	0.314	15578.1	174.2	140.5
	APR	5.63	0.108	0.051	18.0	0.347	0.162	4601.0	88.4	41.5
	MAY	2.64	0.126	0.024	7.75	0.369	0.070	1295.6	104.5	11.7
	JUN	0.75	0.332	0.007	1.25	0.557	0.011	36.3	16.1	0.3
	YEAR									

TABLE 30. (CONTINUED)

NITRATE+NITRITE-N			AMMONIA-N			MEAN DAILY FLOW (M**3/S)	RUNOFF (cm)	TOTAL PRECIPITATION (cm)
TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)	TOTAL LOAD (MT/PERIOD)	[FWM] (MG/L)	YIELD (KG/HA)			
401.1	8.49	3.61	9.2	0.195	0.080	17.7	4.26	
577.1	10.11	5.20	10.9	0.190	0.100	23.7	5.14	
167.2	6.23	1.51	4.8	0.177	0.043	10.1	2.42	
90.9	7.02	0.82	1.1	0.086	0.010	5.01	1.17	
386.9	9.03	3.49	7.0	0.164	0.063	16.1	3.87	
184.3	10.81	1.66	3.0	0.027	6.48	6.48	1.51	
						1.15	0.28	
2.8	0.15	0.03	0.3	0.016	0.003	6.94	1.69	
69.6	2.07	0.63	3.4	0.100	0.031	13.1	3.04	
53.0	3.71	0.48	1.4	0.096	0.013	6.23	1.50	
9.9	2.04	0.09	0.5	0.103	0.005	1.88	0.44	
222.4	5.82	2.01	4.9	0.129	0.044	14.3	3.44	
2167.		19.54	47.9		0.43	10.13	28.71	
			19.1	0.398	0.172	18.0	4.32	
107.0	2.23	0.96	23.1	0.182	0.208	50.8	11.03	
406.6	3.21	3.67	1.8	0.036	0.016	18.9	4.55	
41.8	0.83	0.38	1.5	0.106	0.014	5.64	1.31	
28.3	1.95	0.26	1.5	0.106	0.014	5.64	1.31	
111.6	8.08	1.01	1.8	0.130	0.016	5.18	1.25	
25.9	5.85	0.23	0.8	0.192	0.007	1.71	0.40	
2.23	0.73	0.20	0.38	0.124	0.003	1.15	0.28	
2.59	0.95	0.02	0.37	0.136	0.003	1.02	0.25	
1.44	0.99	0.01	0.28	0.190	0.003	0.56	0.13	
1.43	1.25	0.01	0.06	0.051	0.0005	0.44*	0.10	
4.58	3.47		0.234	0.177		0.51*	0.12	
5.30	2.75	0.005	3.27	1.69	0.029	0.28*	0.07	
739.		6.66	52.7		0.48	8.55	24.22	
1.80	0.38	0.016	9.41	2.01	0.085	1.76	0.42	
14.80	0.79	0.133	44.0	2.35	0.397	7.79	1.69	
825.8	9.23	7.45	21.40	0.24	0.193	33.6	8.07	
547.4	10.50		11.4	0.22	0.103	20.2	4.70	
185.7	8.84	1.67	1.77	0.084	0.016	7.19	1.73	
2.00	0.89	0.02	0.31	0.139	0.003	0.87	0.20	
						4.84	1.16	

TABLE 31. LOADINGS (METRIC TONS) OF CHLORIDE IN THE MAUMEE AND PORTAGE RIVER BASINS

Maumee	1975	1976
Jan	26,011	12,887
Feb	32,734	52,536
Mar	25,146	27,181
Apr	19,868	8,335
May	22,188	8,533
Jun	22,127	5,487
Jul	7,482	3,509
Aug	7,723	1,738
Sep	10,078	895
Oct	5,177	1,590
Nov	5,391	1,109
Dec	24,713	2,336
Year	208,638	126,136
	127 kg/ha/yr	77 kg/ha/yr
Portage		
Jan	1,992	2,356
Feb	2,025	3,992
Mar	1,400	1,892
Apr	876	794
May	1,842	748
Jun	1,011	311
Jul	318	231
Aug	962	194
Sep	1,623	126
Oct	992	105
Nov	543	122
Dec	1,721	178
Year	15,305	11,049
	138 kg/ha/yr	100 kg/ha/yr

4.43 Discussion of Monthly Loadings

The yield per unit area per month from the study area watersheds varied greatly throughout the 2-1/2 years of monitoring. The variation in seasonal loading for all watersheds was much more pronounced than the variation in monthly loadings between watersheds. Table 32 summarizes the yeild per unit area per month of sediment from all watersheds. Tables 33 and 34 express the ratio of each watershed yield to the area weighted mean yield of the experimental plots for sediment and total phosphorus, respectively. Table 32 must be consulted in conjunction with Tables 33 and 34 , because when the magnitude of the watershed and plot yields is not very large,the percent difference is not really significant.

The most interesting point to note is that,in many instances during the late winter and spring months when the magnitudes of the yields are very large, the percentage difference between watersheds may not be very large. That is, the yield per unit area from the Maumee Basin as a whole is similar to the yields from the plots.

In February 1976 the yield from the Maumee was 76% and 127% for sediment and phosphorus, respectively, of the yield from the plots. The same pattern is repeated during several other winter months: December 1975, March 1976, March, April,and May 1977. These six months accounted for 92% of the total sediment load from the Maumee River Basin during the comparison period July 1975 to June 1977. Most of the transport took place in only a few days during those months.

Of the storms in 1975 and 1976 (precipitation records for 1977 were not available) which produced such large sediment transport events,all were basinwide storms with rainfall on the order of 2.5 to 4 cm over a period of two to seven days. Runoff ranged from 60% to 177% of basinwide mean precipitation. Considerable snowmelt was included in the February 1976 storms.

The second major point of comparison is the summer period,when intense storms can produce considerable sediment movement on very small areas without that sediment appearing at the major basin stations. The most significant case in point occurred during August 1975 when total monthly precipitation records were set throughout the Maumee River Basin. The basinwide mean precipitation total was 15.60 cm. It must be said that much of this occurred in relatively long duration summer coldfront storms of much less intensity than the usual summer convective storms. However, the experimental plots did experience their maximum monthly soil loss of the study period during this month: 1,206 kg/ha (basin soil area weighted mean), about 23% of the total soil loss during the comparison period described above.

These storms were basinwide yet produced only 1.04 cm of runoff (6.6% of total precipitation) in the Maumee River at Waterville. Less than 0.5 of 1% of the plot soil loss appeared in runoff at Waterville. The outlets of most of the plots are located where these fields drain into confined natural or manmade drainage channels. The ultimate fate of sediment washed from fields during these periods cannot be accurately determined. There are two major possibilities. First, it may be temporarily stored in the drainage network until the spring,when major runoff events wash it to the river and Lake Erie. Or, since these drainage channels often become completely dry during the late summer, the sediment stored during that period may become so indurated that it can leave the channel only by periodic ditch maintenance dredging. It is well known that ditches in the Maumee Basin are mostly aggrading and do require such maintenance. The lack

TABLE 32. SUMMARY OF MONTHLY UNIT AREA SEDIMENT YIELDS (kg/ha/month)

	Maumee	Portage	Site 2	Site 6	Plots
1975					
Jan	216.0	126.0	102.0	165.0	--
Feb	168.0	138.0	190.0	304.0	--
Mar	39.0	18.0	49.0	90.0	--
Apr	39.0	2.1	33.0	69.0	--
May	112.0	286.0	1,569.0	1,586.0	--
Jun	98.0	35.0	812.0	1,542.0	--
Jul	22.0	1.5	38.0	0.0	149.0
Aug	6.1	0.8	4.0	16.0	1,206.0
Sep	18.0	226.0	13.0	31.0	267.0
Oct	5.7	8.2	2.1	0.0	14.0
Nov	2.8	0.4	33.0	41.0	58.0
Dec	243.0	118.0	195.0	79.0	277.0
1976					
Jan	7.2	28.0	6.8	4.9	50.0
Feb	608.0	310.0	180.0	195.0	829.0
Mar	253.0	7.1	42.0	88.0	645.0
Apr	8.6	1.1	15.0	2.7	3.6
May	16.0	21.0	4.3	1.1	26.0
Jun	8.2	3.2	1.3	0.0	191.0
Jul	4.4	1.7	0.4	0.0	221.0
Aug	1.5	1.2	0.2	0.0	0.0
Sep	0.9	1.6	0.0	0.0	9.0
Oct	1.5	0.0	0.7	0.0	0.0
Nov	0.2	0.0	0.0	0.0	0.0
Dec	0.3	0.0	0.0	0.0	0.0
1977					
Jan	0.0	0.2	--	--	0.0
Feb	0.9	16.0	--	--	136.0
Mar	228.0	140.0	--	--	437.0
Apr	339.0	41.0	--	--	483.0
May	57.0	19.0	--	--	139.0
Jun	2.9	0.0	--	--	37.0

TABLE 33. WATERSHED SEDIMENT YIELD AS PERCENTAGE OF AREA WEIGHTED MEAN PLOT SEDIMENT YIELD†

	Maumee	Portage	Site 2	Site 6
1975				
Jul	15.0	1.0	26.0	0.0
Aug	1.0	0.0	0.0	1.0
Sep	6.7	84.6	5.0	12.0
Oct	42.0	61.0	15.0	0.0
Nov	5.0	1.0	58.0	70.0
Dec	87.0	42.0	70.0	28.0
1976				
Jan	15.0	47.0	14.0	10.0
Feb	76.0	39.0	23.0	24.0
Mar	39.0	1.0	7.0	14.0
Apr	239.0	31.0	416.0	76.0
May	61.0	79.0	16.0	4.0
Jun	4.0	2.0	1.0	0.0
Jul	2.0	1.0	0.0	0.0
Aug	*	*	*	*
Sep	*	*	*	*
Oct	*	*	*	*
Nov	*	*	*	*
Dec	*	*	*	*
1977				
Jan	*	*	*	*
Feb	1.0	12.0	--	--
Mar	52.0	32.0	--	--
Apr	70.0	9.0	--	--
May	41.0	14.0	--	--
Jun	8.0	0.0	--	--

-- No watershed data

* No significant yield from plots

†Weighted mean plot sediment yield is the mean sediment yield from the small watersheds weighted on the basis of distribution of the plot soil type by area in the Maumee Basin.

TABLE 34. WATERSHED TOTAL PHOSPHORUS YIELD AS PERCENTAGE OF AREA WEIGHTED MEAN PLOT TOTAL PHOSPHORUS YIELD

	Maumee	Portage	Site 2	Site 6
1975				
Jul	20.0	0.0	52.0	0.0
Aug	0.0	0.0	0.0	7.0
Sep	32.0	44.0	11.0	74.0
Oct	80.0	260.0	0.0	0.0
Nov	7.0	0.0	223.0	198.0
Dec	77.0	47.0	210.0	197.0
1976				
Jan	111.0	189.0	6.0	0.0
Feb	127.0	82.0	86.0	66.0
Mar	47.0	0.0	9.0	18.0
Apr	*	*	*	*
May	150.0	94.0	0.0	0.0
Jun	7.0	0.0	0.0	0.0
Jul	0.0	0.0	0.0	0.0
Aug	*	*	*	*
Sep	*	*	*	*
Oct	0.0	0.0	0.0	0.0
Nov	*	*	*	*
Dec	*	*	*	*
1977				
Jan	*	*	*	*
Feb	9.0	84.0	--	--
Mar	66.0	44.0	--	--
Apr	64.0	16.0	--	--
May	34.0	15.0	--	--
Jun	0.0	0.0	--	--

-- No watershed data
* No yield from plots

of variability in sediment and nutrient transport between the experimental plots, minor and major **sub-basins** poses a very important point for the management of diffuse source pollutant transport. If it can be assumed, or ultimately proven, that the sediment dislodged from the soil profile during the winter months is delivered to the river mouth monitoring stations at a very high delivery ratio and that sediment dislodged during the summer months does not play an important role in the pollution of the Great Lakes ,then a drastic revision of the land management practices currently promoted by the Soil Conservation Service will be required.

Practices which control summertime erosion will not significantly reduce transport to Lake Erie. The most common tillage practice currently employed in the **Basin,** fall moldboard plowing, may have to be, wherever feasible, abandoned. Modern tillage and non-tillage crop production systems which maintain a cover of the previous year's crop residue on the surface of the land will have to be adopted.

4.44 Point Source Load Summary

The point source loadings for major **sub-basins** of the Maumee River Basin are summarized in Table 35. These loadings were summarized from the detailed point source inventory, which was made by the Lake Erie Wastewater Management Study (1975). The figures for the subtotal for the Maumee River above Waterville and the grand total for the Maumee River at the mouth are larger than the sum of the **sub-basin** totals. This is because the LEWMS report did not prepare **sub-basin** totals from their data files and did not map the location of all point sources. The **sub-basin** totals in Table 35 were made by locating the entities on the maps and ascribing the load to the **sub-basin** . Since many of the very small discharges were not locatable on the maps,their loads do not appear in the **sub-basin** totals, but they are included in the major basin totals.

Table 36 is the monthly **sub-basin loading summary.** It was prepared on the assumption that point source loadings are continuous throughout the year, and is simply one twelfth of the total annual load. Reliable data on the annual loading of suspended solids were not available.

4.45 Diffuse Source Loads

Tables 37-40 present the diffuse source yield per unit area for the Maumee, Portage, Black Creek-Site 2,and Black Creek-Site 6, respectively. Tables 41 and 42 present the total diffuse source loading for the Maumee and the Portage, respectively. Both monthly and annual values for each watershed and parameter are given.

Tables 43 through 49 present the unit area yields by months for all the Maumee Task C Pilot Watershed Study Experimental plots. These are total diffuse source loads (there are no point sources). On the plots which were tiled, Lenawee, Blount, Paulding and Hoytville, the figures represent the total of surface and tile transport. Table 49 is the "basinwide soil area weighted mean" yield of the plots. The yield of each plot was weighted into a mean figure for use in the extrapolation of basinwide loading comparisons. The method of area weighting was described earlier in this report. The yields in Table 48 for the Hoytville soil are the mean of the yields from 8 separate plots. There were no measurements of yield from any of the plots prior to July 1975 except the Hoytville plots, where sampling began in May 1975.

TABLE 35. POINT SOURCE LOADINGS, MAUMEE RIVER BASIN

Basin	Total P (Mt/Yr)	Ortho P (Mt/Yr)	(NO_2+NO_3)-N (Mt/Yr)	NH_3-N (Mt/Yr)	Organic N (Mt/Yr)
St. Joseph	29.1	14.3	37.8	38.0	14.9
St. Marys	5.0	2.5	19.1	20.3	6.1
Tiffin	26.3	13.2	97.7	89.0	27.3
Auglaize (m.s.)*	26.9	13.5	55.6	34.3	14.3
Blanchard*	29.3	14.6	86.0	109 4	32.3
Little Auglaize*	28.6	14.2	31.2	37.3	11.0
Ottawa*	66.1	33.1	43.7	241.5	71.8
Auglaize (Total)	150.9	75.4	216.5	422.6	129.4
Maumee @ Defiance	51.3	25.7	306.8	362.8	108.3
Maumee @ Waterville	30.0	15.0	27.0	58.0	14.6
Subtotal	321.4	160.7	704.9	1026.4	311.3
Maumee Below Waterville	314.2	157.1	919.1	1100.9	326.1
GRAND TOTAL	635.6	317.8	1624.0	2127.3	637.4

*Sum to Auglaize (Total)

TABLE 36. MONTHLY POINT SOURCE LOADINGS, MAUMEE RIVER BASIN

Basin	Total P (Mt/Mo)	Ortho P (Mt/Mo)	(NO_3+NO_2)-N (Mt/Mo)	NH_3-N (Mt/Mo)	Organic-N (Mt/Mo)
St. Joseph	2.43	1.19	3.15	3.17	1.24
St. Marys	.42	.21	1.59	1.69	.51
Tiffin	2.19	1.10	8.14	7.42	2.28
Auglaize (m.s.)*	2.24	1.13	4.63	2.86	1.19
Blanchard*	2.44	1.22	7.17	9.12	2.69
Little Auglaize*	2.38	1.18	2.60	3.11	.92
Ottawa*	5.51	2.76	3.64	20.13	5.98
Auglaize (Total)	12.58	6.28	18.04	35.22	10.78
Maumee @ Defiance	4.28	2.14	25.57	30.23	9.03
Maumee @ Waterville	2.50	1.25	2.25	4.83	1.22
Subtotal	26.78	13.39	58.74	85.53	25.94
Maumee Below Waterville	26.18	13.09	76.59	91.74	27.18
GRAND TOTAL	52.97	26.48	135.33	177.28	53.12

*Sum to Auglaize (Total)

TABLE 37. UNIT AREA YIELDS OF SEDIMENT AND NUTRIENTS FROM MAUMEE RIVER AT WATERVILLE

	Dissolved Inorganic Phosphorus	Total Phosphorus	Suspended Sediment	NO_3-N	NH_4-N
1975			kg/ha/month		
Jan	0.029	0.430	215.7	3.46	0.05
Feb	0.052	0.442	168.2	3.14	0.06
Mar	0.043	0.145	39.3	1.94	0.06
Apr	0.017	0.071	39.2	1.97	0.00
May	0.025	0.200	112.4	2.47	0.00
Jun	0.030	0.144	98.1	2.64	0.00
Jul	0.001	0.020	22.2	0.27	0.00
Aug	0.000	0.000	6.1	0.05	0.00
Sep	0.013	0.047	18.3	0.24	0.00
Oct	0.000	0.004	5.7	0.13	0.00
Nov	0.000	0.005	2.8	0.10	0.00
Dec	0.040	0.373	242.5	2.25	0.00
1976					
Jan	0.026	0.052	7.2	0.63	0.07
Feb	0.136	0.902	608.2	4.03	0.28
Mar	0.018	0.382	252.7	0.70	0.00
Apr	0.000	0.005	8.6	0.36	0.00
May	0.002	0.027	15.9	0.71	0.00
Jun	0.000	0.008	8.2	0.50	0.00
Jul	0.000	0.000	4.4	0.13	0.00
Aug	0.000	0.000	1.5	0.00	0.00
Sep	0.000	0.000	0.9	0.00	0.00
Oct	0.000	0.000	1.5	0.00	0.00
Nov	0.000	0.000	0.2	0.00	0.00
Dec	0.000	0.000	0.3	0.00	0.00
1977					
Jan	0.000	0.000	0.0	0.00	0.00
Feb	0.016	0.019	0.9	0.08	0.08
Mar	0.051	0.433	227.9	4.51	0.19
Apr	0.041	0.551	338.7	4.21	0.01
May	0.010	0.098	57.3	1.69	0.00
Jun	0.000	0.000	2.9	0.03	0.00
			kg/ha/year		
1975	0.249	1.882	970	18.672	0.193
1976	0.182	1.376	910	7.052	0.364
1977	0.117	1.101	628	10.528	0.295

TABLE 38. UNIT AREA YIELDS OF SEDIMENT AND NUTRIENTS FROM PORTAGE RIVER AT WOODVILLE

	Dissolved Inorganic Phosphorus	Total Phosphorus	Suspended Sediment	NO_3-N	NH_4-N
1975			kg/ha/month		
Jan	0.037	0.221	125.6	3.54	0.00
Feb	0.049	0.262	137.7	5.13	0.01
Mar	0.023	0.040	17.5	1.48	0.00
Apr	0.007	0.002	2.1	0.72	0.00
May	0.031	0.304	285.5	3.41	0.00
Jun	0.020	0.054	34.6	1.59	0.00
Jul	0.000	0.000	1.5	0.00	0.00
Aug	0.000	0.000	0.8	0.00	0.00
Sep	0.034	0.064	226.0	0.55	0.00
Oct	0.000	0.013	8.2	0.40	0.00
Nov	0.000	0.000	0.4	0.01	0.00
Dec	0.025	0.228	117.5	1.93	0.00
1976					
Jan	0.042	0.089	28.1	0.89	0.07
Feb	0.117	0.581	309.8	3.72	0.12
Mar	0.000	0.000	7.1	0.30	0.00
Apr	0.000	0.000	1.1	0.19	0.00
May	0.001	0.017	20.7	0.93	0.00
Jun	0.000	0.000	3.2	0.16	0.00
Jul	0.000	0.000	1.7	0.00	0.00
Aug	0.000	0.000	1.2	0.00	0.00
Sep	0.000	0.000	1.6	0.00	0.00
Oct	0.000	0.000	0.0	0.00	0.00
Nov	0.000	0.000	0.0	0.00	0.00
Dec	0.000	0.000	0.0	0.00	0.00
1977					
Jan	0.026	0.026	0.2	0.00	0.00
Feb	0.117	0.176	16.4	0.06	0.31
Mar	0.075	0.288	140.1	7.37	0.10
Apr	0.038	0.137	41.2	4.86	0.01
May	0.011	0.044	19.4	1.60	0.00
Jun	0.000	0.000	0.0	0.00	0.00
			kg/ha/month		
1975	0.226	1.188	957	18.751	0.014
1976	0.161	0.688	375	6.186	0.208
1977	0.267	0.672	217	13.888	0.425

TABLE 39. UNIT AREA YIELDS OF SEDIMENT AND NUTRIENTS FROM BLACK CREEK WATERSHED: SITE 2

	Dissolved Inorganic Phosphorus	Total Phosphorus	Suspended Sediment	NO_3-N	NH_4-N
1975			kg/ha/month		
Jan	0.033	0.197	101.70	3.54	0.151
Feb	0.024	0.618	189.95	2.63	0.241
Mar	0.010	0.066	49.38	2.19	0.122
Apr	0.013	0.048	32.50	1.61	0.159
May	0.043	2.527	1569.43	1.50	0.520
Jun	0.045	1.904	811.80	3.11	0.153
Jul	0.000	0.053	38.19	0.13	0.007
Aug	0.000	0.000	3.96	0.01	0.000
Sep	0.000	0.016	12.75	0.10	0.010
Oct	0.000	0.000	2.05	0.00	0.000
Nov	0.010	0.156	33.45	0.37	0.057
Dec	0.023	1.014	194.83	1.66	0.082
1976					
Jan	0.000	0.003	6.76	0.16	0.043
Feb	0.062	0.610	180.42	1.55	0.209
Mar	0.010	0.076	42.47	0.90	0.059
Apr	0.003	0.029	14.98	0.78	0.089
May	0.000	0.000	4.26	0.19	0.000
Jun	0.000	0.000	1.25	0.03	0.000
Jul	0.000	0.000	0.38	0.00	0.000
Aug	0.000	0.000	0.21	0.00	0.000
Sep	0.000	0.000	0.00	0.00	0.000
Oct	0.000	0.000	0.67	0.00	0.000
Nov	0.000	0.000	0.00	0.00	0.000
Dec	0.000	0.000	0.00	0.00	0.000
			kg/ha/year		
1975	0.199	6.599	3040	16.826	1.502
1976	0.075	0.717	251	3.617	0.401
1977	0.000	0.000	0	0.000	0.000

TABLE 40. UNIT AREA YIELDS OF SEDIMENT AND NUTRIENTS FROM BLACK CREEK WATERSHED: SITE 6

	Dissolved Inorganic Phosphorus	Total Phosphorus	Suspended Sediment	NO_3-N	NH_4-N
1975			kg/ha/month		
Jan	0.026	0.278	164.60	1.19	0.278
Feb	0.031	0.435	303.57	0.80	0.227
Mar	0.030	0.139	89.92	1.32	0.130
Apr	0.025	0.109	69.37	1.03	0.109
May	0.026	1.481	1585.64	1.02	0.135
Jun	0.013	1.391	1542.06	0.95	0.050
Jul	0.000	0.000	0.00	0.00	0.000
Aug	0.000	0.022	16.24	0.00	0.000
Sep	0.000	0.109	31.05	0.00	0.000
Oct	0.000	0.000	0.00	0.00	0.000
Nov	0.013	0.139	40.80	0.24	0.025
Dec	0.009	0.955	78.63	0.50	0.043
1976					
Jan	0.000	0.000	4.86	0.00	0.082
Feb	0.102	0.471	195.00	0.87	0.325
Mar	0.017	0.148	87.75	0.59	0.048
Apr	0.000	0.000	2.73	0.00	0.000
May	0.000	0.000	1.13	0.00	0.000
Jun	0.000	0.000	0.00	0.00	0.000
Jul	0.000	0.000	0.00	0.00	0.000
Aug	0.000	0.000	0.00	0.00	0.000
Sep	0.000	0.000	0.00	0.00	0.000
Oct	0.000	0.000	0.00	0.00	0.000
Nov	0.000	0.000	0.00	0.00	0.034
Dec	0.000	0.000	0.00	0.00	0.000
			kg/ha/year		
1975	0.173	5.057	3922	7.056	0.998
1976	0.119	0.619	291	1.459	0.489
1977	0.000	0.000	0	0.000	0.000

TABLE 41. TOTAL DIFFUSE LOADS OF SEDIMENT AND NUTRIENTS FROM MAUMEE RIVER AT WATERVILLE

	Dissolved Inorganic Phosphorus	Total Phosphorus	Suspended Sediment	NO_3-N	NH_4-N
1975	metric tons/month				
Jan	48.3	714	357926	5737	93
Feb	85.7	734	279076	5210	115
Mar	71.3	240	65162	3226	112
Apr	27.4	118	65010	3266	0
May	41.6	332	186394	4100	0
Jun	49.0	239	162765	4388	0
Jul	1.3	33	36859	455	0
Aug	0.0	0	10103	82	0
Sep	22.1	77	30387	392	0
Oct	0.0	7	9452	220	0
Nov	0.0	9	4617	167	0
Dec	67.1	619	402244	3734	0
1976					
Jan	43.7	87	12016	1047	126
Feb	226.3	1497	1008933	6681	472
Mar	29.5	634	419312	1165	7
Apr	0.0	9	14256	590	0
May	3.2	44	26366	1177	0
Jun	0.0	13	13593	824	0
Jul	0.0	0	7322	216	0
Aug	0.0	0	2446	0	0
Sep	0.0	0	1488	0	0
Oct	0.0	0	2489	0	0
Nov	0.0	0	348	0	0
Dec	0.0	0	536	0	0
1977					
Jan	0.0	0	75	0	0
Feb	26.7	31	1425	138	139
Mar	84.7	718	378017	7482	327
Apr	67.4	914	561921	6986	23
May	15.8	163	94990	2808	0
Jun	0.0	0	4770	51	0
	metric tons/year				
1975	413.728	3122	1609989	30977	320
1976	302.698	2283	1509101	11699	605
1977	194.713	1826	1041199	17465	489

TABLE 42. TOTAL DIFFUSE LOADS OF SEDIMENT AND NUTRIENTS FROM PORTAGE RIVER AT WOODVILLE

	Dissolved Inorganic Phosphorus	Total Phosphorus	Suspended Sediment	NO3-N	NH_4-N
1975	metric tons/month				
Jan	4.1	25	13928	392	0
Feb	5.5	29	15271	569	2
Mar	2.6	4	1943	164	0
Apr	0.7	0	235	79	0
May	3.5	34	31657	378	0
Jun	2.2	6	3833	176	0
Jul	0.0	0	169	0	0
Aug	0.0	0	88	0	0
Sep	3.8	7	25058	61	0
Oct	0.0	1	905	44	0
Nov	0.0	0	42	1	0
Dec	2.8	25	13035	214	0
1976					
Jan	4.7	10	3115	98	9
Feb	13.0	64	34356	413	14
Mar	0.0	0	787	33	0
Apr	0.0	0	119	21	0
May	0.1	2	2293	103	0
Jun	0.0	0	359	17	0
Jul	0.0	0	184	0	0
Aug	0.0	0	138	0	0
Sep	0.0	0	181	0	0
Oct	0.0	0	0	0	0
Nov	0.0	0	0	0	0
Dec	0.0	0	0	0	0
1977					
Jan	2.9	3	20	0	0
Feb	12.9	20	1822	7	35
Mar	8.3	32	15540	817	11
Apr	4.3	15	4565	539	1
May	1.2	5	2157	177	0
Jun	0.0	0	0	0	0
	metric tons/year				
1975	25.106	132	106163	2080	2
1976	17.857	76	41533	686	23
1977	29.596	75	24104	1540	47

TABLE 43. UNIT AREA YIELDS OF SEDIMENT AND NUTRIENTS FROM WATERSHED: 111
SOILTYPE: ROSELMS

	Dissolved Inorganic Phosphorus	Total Phosphorus	Suspended Sediment	NO_3-N	NH_4-N
1975	---------------------- kg/ha/month			----------------------	
Jan					
Feb					
Mar					
Apr					
May					
Jun					
Jul					
Aug	0.000	0.420	960.00	0.39	0.180
Sep	0.030	0.250	520.00	0.16	0.000
Oct	0.000	0.000	0.00	0.00	0.000
Nov	0.010	0.000	96.00	0.13	0.210
Dec	0.020	0.250	207.00	1.56	0.100
1976					
Jan	0.010	0.000	12.00	1.84	0.000
Feb	0.114	1.005	1035.71	7.80	0.797
Mar	0.040	0.880	1727.00	6.22	0.000
Apr	0.010	0.000	57.00	1.48	0.300
May	0.010	0.360	489.00	2.90	0.000
Jun	0.000	0.020	23.00	0.11	0.000
Jul	0.020	0.200	402.00	2.33	0.590
Aug	0.000	0.000	0.00	0.00	0.000
Sep	0.000	0.000	0.00	0.00	0.000
Oct	0.000	0.000	0.00	0.00	0.000
Nov	0.000	0.000	0.00	0.00	0.000
Dec	0.000	0.000	0.00	0.00	0.000
1977					
Jan	0.000	0.000	0.00	0.00	0.000
Feb	0.010	0.000	93.00	1.61	0.000
Mar	0.010	0.390	252.00	2.45	0.000
Apr	0.020	0.370	680.00	5.07	0.000
May	0.010	0.410	258.00	0.99	0.000
Jun	0.000	0.000	0.00	0.00	0.000
	---------------------- kg/ha/year			----------------------	
1975	0.060	0.920	1783	2.240	0.490
1976	0.204	2.465	3746	22.679	1.687
1977	0.050	1.170	1283	10.120	0.000

TABLE 44. UNIT AREA OF SEDIMENT AND NUTRIENTS FROM WATERSHED: 201
SOILTYPE: ROSELMS

	Dissolved Organic Phosphorus	Total Phosphorus	Suspended Sediment	NO_3-N	NH_4-N
1975	kg/ha/month				
Jan					
Feb					
Mar					
Apr					
May					
Jun					
Jul	0.000	0.000	0.00	0.15	0.430
Aug	0.040	0.250	4153.99	1.86	1.570
Sep	0.030	0.190	248.00	0.00	0.000
Oct	0.000	0.020	11.00	0.01	0.000
Nov	0.020	0.040	74.00	1.41	0.000
Dec	0.020	1.040	596.00	2.09	0.130
1976					
Jan	0.000	0.000	62.00	2.15	0.380
Feb	0.093	0.725	793.36	0.31	0.259
Mar	0.020	0.880	1186.00	1.43	0.020
Apr	0.000	0.000	0.00	0.00	0.000
May	0.000	0.000	0.00	0.00	0.000
Jun	0.000	0.000	0.00	0.00	0.000
Jul	0.000	0.210	279.00	1.34	0.080
Aug	0.000	0.000	0.00	0.00	0.000
Sep	0.000	0.000	0.00	0.00	0.000
Oct	0.000	0.000	0.00	0.00	0.000
Nov	0.000	0.000	0.00	0.00	0.000
Dec	0.000	0.000	0.00	0.00	0.000
1977					
Jan	0.000	0.000	0.00	0.00	0.000
Feb	0.030	0.410	237.00	2.51	0.000
Mar	0.020	1.000	741.00	1.94	0.000
Apr	0.010	0.370	768.00	1.04	0.000
May	0.010	0.330	191.00	0.00	0.000
Jun	0.000	0.000	0.00	0.00	0.000
	kg/ha/year				
1975	0.110	1.540	5083	5.520	2.130
1976	0.113	1.815	2320	5.231	0.739
1977	0.070	2.110	1937	5.490	0.000

TABLE 45. UNIT AREA YIELDS OF SEDIMENT AND NUTRIENTS FROM WATERSHED: 301 + 302
SOILTYPE: LENAWEE

	Dissolved Inorganic Phosphorus	Total Phosphorus	Suspended Sediment	NO_3-N	NH_4-N
1975	----------	----------	kg/ha/month	----------	----------
Jan					
Feb					
Mar					
Apr					
May					
Jun					
Jul	0.000	0.650	13.00	0.53	0.020
Aug	0.000	0.000	0.00	0.00	0.040
Sep	0.000	0.000	0.00	0.00	0.000
Oct	0.000	0.000	0.00	0.00	0.000
Nov	0.000	0.010	4.00	0.26	0.130
Dec	0.050	0.280	139.00	10.09	0.340
1976					
Jan	0.000	0.000	0.00	0.14	0.040
Feb	0.114	0.238	768.50	2.35	0.394
Mar	0.010	0.040	25.00	2.41	0.000
Apr	0.000	0.000	0.00	0.52	0.000
May	0.000	0.000	1.00	0.41	0.000
Jun	0.000	0.000	0.00	0.01	0.000
Jul	0.000	0.000	0.00	0.01	0.000
Aug	0.000	0.000	0.00	0.00	0.000
Sep	0.000	0.000	0.00	0.00	0.000
Oct	0.000	0.000	0.00	0.00	0.000
Nov	0.000	0.000	0.00	0.00	0.000
Dec	0.000	0.000	0.00	0.00	0.000
1977					
Jan	0.000	0.000	0.00	0.00	0.000
Feb	0.160	0.290	38.00	1.39	0.580
Mar	0.540	0.350	216.00	10.63	0.010
Apr	0.000	0.030	4.00	0.88	0.000
May	0.000	0.100	1.00	2.09	0.000
Jun	0.000	0.000	0.00	0.00	0.000
	----------	----------	kg/ha/year	----------	----------
1975	0.050	0.940	156	10.880	0.530
1976	0.124	0.278	794	5.851	0.434
1977	0.700	0.770	259	14.990	0.590

TABLE 46. UNIT AREA YIELDS OF SEDIMENT AND NUTRIENTS FROM WATERSHED: 401 + 402
SOILTYPE: BLOUNT

	Dissolved Inorganic Phosphorus	Total Phosphorus	Suspended Sediment	NO_3-N	NH_4-N
1975	kg/ha/month				
Jan					
Feb					
Mar					
Apr					
May					
Jun					
Jul	0.000	0.000	11.00	0.50	0.120
Aug	0.020	0.800	643.00	0.96	0.900
Sep	0.000	0.080	54.00	0.15	0.040
Oct	0.000	0.010	0.00	0.05	0.000
Nov	0.030	0.160	84.00	2.72	0.440
Dec	0.030	0.350	224.00	4.87	0.230
1976					
Jan	0.000	0.040	42.00	1.05	0.900
Feb	0.042	0.797	1179.68	6.63	0.093
Mar	0.100	1.110	1109.00	2.65	0.010
Apr	0.000	0.010	1.00	1.09	0.000
May	0.000	0.010	2.00	0.70	0.000
Jun	0.000	0.390	654.00	1.26	0.000
Jul	0.030	0.700	714.00	1.34	0.310
Aug	0.000	0.000	0.00	0.00	0.000
Sep	0.000	0.000	0.00	0.00	0.000
Oct	0.000	0.350	0.00	0.00	0.000
Nov	0.000	0.000	0.00	0.00	0.000
Dec	0.000	0.000	0.00	0.00	0.000
1977					
Jan	0.000	0.000	0.00	0.00	0.000
Feb	0.000	0.000	103.00	2.59	0.000
Mar	0.010	0.640	397.00	13.76	0.050
Apr	0.040	1.590	648.00	13.37	0.000
May	0.010	0.070	12.00	1.91	0.000
Jun	0.000	0.000	0.00	0.00	0.000
	kg/ha/year				
1975	0.080	1.400	1016	9.250	1.730
1976	0.171	3.407	3702	14.718	1.313
1977	0.060	2.300	1160	31.630	0.050

TABLE 47. UNIT AREA YIELDS OF SEDIMENT AND NUTRIENTS FROM WATERSHED: 501 + 502
SOILTYPE: PAULDING

	Dissolved Inorganic Phosphorus	Total Phosphorus	Suspended Sediment	NO_3-N	NH_4-N
1975	kg/ha/month				
Jan					
Feb					
Mar					
Apr					
May					
Jun	0.200	0.000	0.00	0.00	0.000
Jul	0.000	0.020	1768.00	0.57	0.350
Aug	0.000	0.000	105.00	0.11	0.050
Sep	0.090	0.860	2040.00	2.29	0.070
Oct	0.010	0.070	119.00	0.80	0.010
Nov	0.030	0.160	106.00	2.27	0.290
Dec	0.020	1.220	534.00	1.46	0.540
1976					
Jan	0.020	0.460	281.00	1.37	0.840
Feb	0.145	0.994	1400.28	2.15	0.870
Mar	0.120	3.090	2804.00	3.10	0.140
Apr	0.000	0.000	0.00	0.24	0.000
May	0.000	0.010	0.00	0.18	0.000
Jun	0.000	0.070	76.00	8.38	0.000
Jul	0.000	0.000	5.00	0.02	0.000
Aug	0.000	0.000	0.00	0.00	0.000
Sep	0.000	0.000	0.00	0.00	0.000
Oct	0.000	0.000	0.00	0.00	0.000
Nov	0.000	0.000	0.00	0.00	0.000
Dec	0.000	0.000	0.00	0.00	0.000
1977					
Jan	0.000	0.000	0.00	0.00	0.000
Feb	0.860	0.000	511.00	6.69	1.310
Mar	0.020	1.500	1351.00	3.12	0.000
Apr	0.260	3.350	1118.00	4.27	0.000
May	0.010	1.550	868.00	1.94	0.000
Jun	0.000	0.000	0.00	0.00	0.000
	kg/ha/year				
1975	0.150	2.330	4672	7.500	1.310
1976	0.285	4.624	4566	15.444	1.850
1977	1.150	6.400	3848	16.020	1.310

TABLE 48. UNIT AREA YIELDS OF SEDIMENT AND NUTRIENTS FROM WATERSHED: 6_1 + 6_2
SOILTYPE: HOYTVILLE

	Dissolved Inorganic Phosphorus	Total Phosphorus	Suspended Sediment	NO_3-N	NH_4-N
1975			kg/ha/month		
Jan					
Feb					
Mar					
Apr					
May	0.039	0.000	804.00	9.26	0.000
Jun	0.037	0.000	244.00	3.54	0.000
Jul	0.000	0.000	10.10	0.04	0.000
Aug	0.008	0.108	65.00	0.34	0.000
Sep	0.022	0.202	26.00	1.74	0.000
Oct	0.008	0.023	7.00	0.36	0.000
Nov	0.045	0.030	17.00	0.16	0.000
Dec	0.116	0.163	17.00	3.17	0.000
1976					
Jan	0.054	0.101	1.40	1.44	0.000
Feb	0.196	0.428	40.39	6.21	0.000
Mar	0.031	0.163	29.00	2.92	0.000
Apr	0.007	0.052	2.60	0.71	0.000
May	0.008	0.062	4.80	1.87	0.000
Jun	0.000	0.007	1.40	0.11	0.000
Jul	0.008	0.015	2.90	0.02	0.000
Aug	0.000	0.008	0.13	0.00	0.000
Sep	0.000	0.000	0.00	0.00	0.000
Oct	0.000	0.000	0.00	0.00	0.000
Nov	0.000	0.000	0.00	0.00	0.000
Dec	0.000	0.000	0.00	0.00	0.000
1977					
Jan	0.000	0.000	0.00	0.00	0.000
Feb	0.217	0.343	8.00	0.72	0.000
Mar	0.039	0.271	10.00	4.77	0.008
Apr	0.022	0.188	2.00	5.18	0.007
May	0.023	0.163	42.00	3.22	0.000
Jun	0.022	0.307	178.00	0.72	0.000
			kg/ha/year		
1975	0.275	0.527	1190	18.605	0.000
1976	0.304	0.836	83	13.285	0.000
1977	0.324	1.272	240	14.606	0.015

TABLE 49. UNIT AREA YIELDS OF SEDIMENT AND NUTRIENTS OF ALL PLOTS (WEIGHTED BY DISTRIBUTION OF SOILTYPE IN THE MAUMEE BASIN)

	Dissolved Inorganic Phosphorus	Total Phosphorus	Suspended Sediment	NO_3-N	NH_4-N
1975			kg/ha/month		
Jan					
Feb					
Mar					
Apr					
May					
Jun					
Jul	0.000	0.101	148.60	2.26	0.157
Aug	0.021	0.302	1205.50	0.73	0.627
Sep	0.020	0.147	266.80	0.54	0.014
Oct	0.000	0.005	13.50	0.50	0.000
Nov	0.012	0.070	58.10	1.31	0.172
Dec	0.019	0.484	277.30	4.19	0.202
1976					
Jan	0.003	0.047	49.50	1.34	0.407
Feb	0.067	0.737	828.99	3.28	0.261
Mar	0.041	0.808	645.30	2.65	0.012
Apr	0.001	0.000	3.60	0.64	0.015
May	0.001	0.018	26.10	0.74	0.000
Jun	0.000	0.118	190.70	1.03	0.000
Jul	0.000	0.251	221.10	0.80	0.140
Aug	0.000	0.000	0.00	0.00	0.000
Sep	0.000	0.000	0.00	0.00	0.000
Oct	0.000	0.000	0.00	0.00	0.000
Nov	0.000	0.000	0.00	0.00	0.000
Dec	0.000	0.000	0.00	0.00	0.000
1977					
Jan	0.000	0.000	0.00	0.00	0.000
Feb	0.150	0.210	136.00	2.28	0.190
Mar	0.100	0.660	437.00	7.26	0.020
Apr	0.040	0.860	483.00	5.80	0.000
May	0.010	0.290	139.00	1.73	0.000
Jun	0.000	0.060	37.00	0.15	0.000
			kg/ha/year		
1975	0.072	1.109	1970	9.530	1.172
1976	0.113	1.979	1965	10.483	0.835
1977	0.300	2.080	1232	17.220	0.210

4.46 Precipitation in the Maumee River Basin 1975-76

Rainfall data for the period 1975-76 was obtained for all hourly recording rain gauge stations in Ohio and Indiana. There are no such stations in or near the Michigan portion of the Maumee Basin. These records of hourly precipitation are readily available from the National Climatic Center of the National Oceanic and Atmospheric Administration. There are 14 weather reporting stations in or very near the Maumee Basin with recording rain gauges. Of these 14, 8 had sufficiently complete records of rainfall during the 1975-76 period for this analysis. Figure 1 shows the location of all recording rain gauges in and near the Maumee Basin.

Since this analysis is primarily concerned with the relationships of rainfall erosion and runoff,it was necessary to determine whether precipitation was in the form of rain or snow (or ice, etc.). This was done through the use of NOAA's Local Climatological Data reports for the cities of Toledo and Fort Wayne. These monthly reports are available only for primary weather data-gathering stations in larger cities. Precipitation, rain or snow, moisture equivalent, depth of snow on the ground, daily ranges and means of temperatures as given in the reports provide indices of the nature of the storms. This information was used to determine whether a particular storm was rain or snow. The effect of snow on the ground was not taken into account rigorously in the calculation of rainfall erosion indices. This will not be a serious effect because it seemed that there was usually very little snow on the ground at the beginning of most rainfall storms.

1975 and 1976 were years of moderate extremes of precipitation in the Maumee River Basin. Table 50 summarizes the total precipitation, normals, and departures from normal for the eight stations with adequate precipitation data for the two years. The last column, Area Weight, indicates the weight of the given station, determined by the method of Thiessen (1911), in the calculation of area weighted mean basin precipitation.

1975 was wet, 97.5 cm (38.40 in.), 11.0 cm (4.34 in.) above normal; 1976 was dry, 71.27 cm (28.06 in.), 15.2 cm (6.00 in.) below normal. Normal total annual precipitation for the basin is 86.5 cm (34.06 in.). The mean of the two years was 84.4 cm (33.22 in.) and only 2.1 cm (0.81 in.) below normal.

Although it would appear that the water budget of the watershed was not degraded over the period,it will become apparent in the discussion of runoff (below) that the excesses of 1975 had little effect on the deficiency of 1976.

The distribution of the deviance in precipitation is also interesting. Figure 27 is a graph of normal 1975 and 1976 monthly precipitation at Defiance, Ohio. During both 1975 and 1976 precipitation did not deviate from normal to any great degree during the early months of the year, January through May, or during the fall months, September through October. The greatest deviations took place during the summer of 1975, June, July, and August, when for the three months precipitation was a total of 21.9 cm (8.64 in.) above normal. During 1976 precipitation was considerably below normal in April, May, June, August, November,and December. The implications of these deviations on runoff, gross erosion,and sediment delivery will be discussed in later sections.

TABLE 50

SUMMARY OF PRECIPITATION DATA

MAUMEE RIVER BASIN

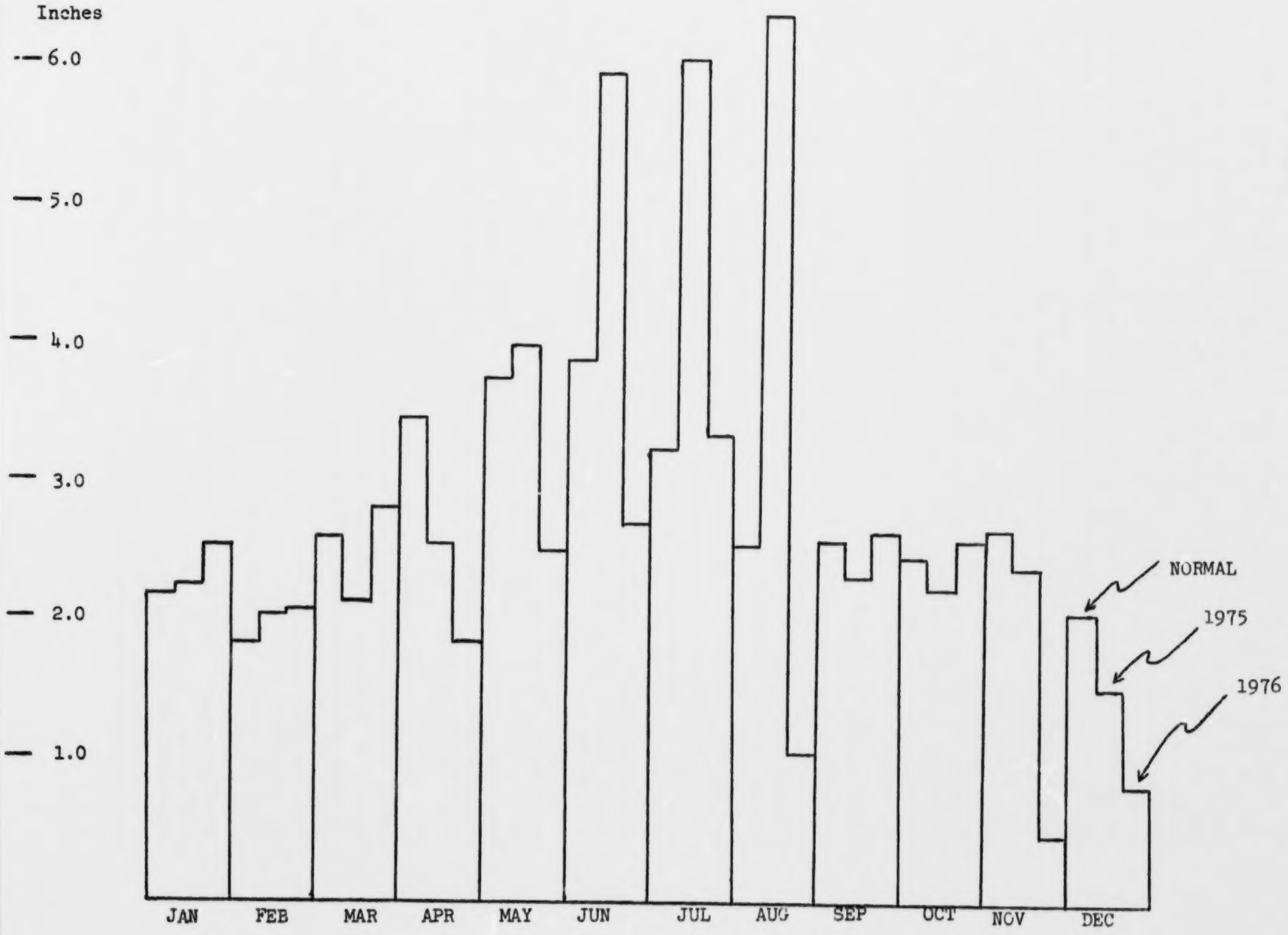
	Normal cm.	1975	Departure	1976	Departure	Area Weight
Defiance	84.63	101.2	16.6	64.9	-19.7	
Findlay	90.47	98.0	7.6	79.5	-11.0	
Lima	90.27	95.3	5.0	82.3	- 8.0	
Pandora	90.37	98.9	8.6	65.9	-24.5	
St. Marys	86.79	90.9	4.1	69.9	-16.9	
Toledo	80.09	98.0	17.9	73.1	- 7.0	
Ft. Wayne	90.93	93.3	2.4	66.8	-24.2	
Kendallville	87.78	101.0	10.6	87.4	- .4	
Maumee Basin	86.5	97.5	11.0	71.27	-15.2	

1. Mean of Lima and Findlay
2. Mean of Ft. Wayne and Defiance

Mean 1975, 76 : 84.4

Departure : -2.1

FIGURE 27. NORMAL, 1975 AND 1976 PRECIPITATION AT DEFIANCE, OHIO



In his description of the rainfall erosion factor, R, of the Universal Soil Loss Equation,Wischmeier (1965) defines a storm as a period of precipitation of 1.27 cm (0.5 in.) unbroken by 6 hours of non-measurable precipitation. This definition has generally been used in this analysis although storms of as little as 1.09 cm (0.43 in.) have been included. Tables 51 and 52 summarize the storm and non-storm rainfall at each station and for the Maumee Basin for 1975 and 1976, respectively. There is very little difference between the two years in the percentage of rainfall that came in storms and non-storms, 60.8% as storms in 1975 and 55.9% as storms in 1976. There is, of course, a great difference in total storm precipitation between the two years because of the large difference in total rainfall. Rainfall meeting the definition of a storm fell somewhere in the Maumee River Basin on a total of 67 days in 1975 and 52 days in 1976. Of the total number of storm days, 16 in 1975 and 10 in 1976 were of a frontal or basinwide nature. These storms are usually associated with warm fronts advancing across the basin from the west or southwest. This is apparent from the intensity and duration of the rainfall events and the relative time of beginning of the storms as they advance across the basin. The remainder are convective and cold front storms,which may be of high intensity but usually have a shorter duration and are more localized.

4.47 Storms and Runoff

There are several very important questions about the relationships of storms, runoff, gross erosion,and sediment delivery which remain largely unanswered. It has been common practice to treat the summer through early fall months, when the most energetic storms occur, as the most serious period of erosion. If bare soil and identical antecedent moisture conditions are assumed,the previous statement is true, but this is seldom the case in a natural system. During July and August, when the most intense thunderstorms may occur, the canopy cover in a corn-soybean agricultural watershed may be nearly 100%. The energy of these storms, as accumulated for calculation of the rainfall erosion factor, may be almost completely dissipated on the leaves of the crops. Large raindrops are broken down and finally reach the surface at reduced velocity and total kinetic energy. Gross sheet erosion is drastically reduced, compaction and sealing of the soil surface is reduced, and infiltration remains higher for a longer time during the storm which is usually of shorter duration than the winter storm. Runoff from equivalent total precipitation storms in the summer is only a small fraction of the runoff from the similar storm in the winter.

Table 53 is a summary of all storms in the Maumee Basin during 1975 and 1976 which produced significant rises in the hydrograph at Waterville, Ohio. The Waterville gauge drainage area, 16,353 sq km (6,314 sq mi) is the farthest gauge downstream and measures almost total basin runoff. The hydrographs of sub-basins have not been examined. The numerals identifying the type of storm indicate how widespread the occurrence of rainfall was over the basin: (1) All stations reported storm class rainfall on the same day -- a basinwide storm; (2) All but 1 or 2 stations report a storm rainfall on the same day -- a near basinwide storm; (3) All stations report storm rainfall over a period of 2 or more days, but all stations do not report storms on every day -- a basinwide storm of extended duration; and (4) Less than 6 stations reported storm rainfall, but there was a significant rise in the hydrograph at Waterville. P is the basinwide area weighted total precipitation.

TABLE 51

PRECIPITATION OF STORM AND NON-STORM PERIODS - 1975

1975	STORM	%	NON-STORM	%
Defiance	62.8	62.0	38.5	38.0
Findlay	64.5	65.8	33.5	34.2
Lima	55.1	57.9	40.1	42.1
Pandora	63.2	63.9	35.8	36.1
St. Marys	52.3	57.5	38.6	42.5
Toledo	56.7	57.9	41.3	42.1
Ft. Wayne	59.9	64.2	33.4	35.8
Kendallville	56.1	55.6	44.8	44.4
MAUMEE BASIN	59.3	60.8	38.2	39.2

TABLE 52

PRECIPITATION OF STORM AND NON-STORM PERIODS - 1976

1976	STORM	%	NON-STORM	%
Defiance	31.5	48.5	33.4	51.5
Findlay	45.2	56.9	34.3	43.1
Lima	46.5	56.5	35.8	43.5
Pandora	40.2	60.9	25.7	39.1
St. Marys	38.9	55.6	31.0	44.4
Toledo	38.1	52.1	35.0	47.9
Ft. Wayne	41.3	61.8	25.5	38.2
Kendallville	61.5	68.4	28.4	31.6
MAUMEE BASIN	39.8	55.9	31.4	44.1

TABLE 53

SUMMARY OF STORMS PRODUCING SIGNIFICANT RUNOFF

STORM NUMBER	STORM DATE	TYPE	TOTAL BASIN PRECIP (cm)	MAXIMUM FLOW (m^3/sec)	PEAK FLUX (MT/DAY)
	1975				
1	1/8	2	1.49	895.	60,872.
2	1/28	1	1.68	569.	27,669.
3	2/22	1	2.79	1,399.	106,141.
4	3/7	2	1.42	282.	1,996.
5	3/28	2	1.32	411.	7,711.
6	4/18	2	1.37	175.	1,034.
7	4/23-4/24	4	0.63	413.	11,431.
8	4/27	4	0.58	362.	4,863.
9	5/5	4	1.68	382.	6,350.
10	5/20-5/22	3	3.30	612.	43,364.
11	6/1 -6/11	3	1.80	385.	9,435.
12	6/11	1	2.16	170.	2,867.
13	6/14	1	1.88	640.	37,376.
14	6/22-6/25	4	0.61	255.	7,484.
15	7/3	4	1.88	135.	1,869.
16	7/18-7/19	3	4.22	187.	2,504.
17	8/1 -8/5	3	4.57	61.2	392.
18	8/15	2	2.31	91.8	699.
19	8/21-8/22	3	2.36	161.	2,123.
20	8/26-8/30	3	2.57	155.	3,329.
21	9/5	2	1.93	234.	4,200.
22	9/11	2	2.36	176.	3,003
23	10/17-10/18	3	2.06	154.	1,089.
24	11/29-11/30	4	1.27	388.	5,969.
25	12/6	4	.38	235.	1,080
26	12/14-12/15	1	2.54	869.	78,926
	1976				
1	1/25	4	1.04	462.	2,359.
2	2/16 to	1	3.94	1,940.	127,914.
	2/22	3		1,926.	57,607.
3	3/3 -3/5	3	2.62	1,450	84,369.
4	4/24-4/25	3	3.12	317.	2,005.
5	5/6	1	2.24	182.	1,016.
6	5/30-6/1	2	1.93	160.	595.
7	6/18	1	2.18	31.1	224.
8	6/23-6/24	3	2.57	78.2	466.
9	8/5 -8/6	2	1.60	14.4	59.9

A 1.68 cm (0.66 in.) basinwide storm during the winter (1/28/75) produced a peak mean daily discharge of 569 cu.m/s (20,100 cfs),while a 2.16 cm (0.85 in.) basinwide storm during the summer gave a peak mean daily discharge of only 170 cu m/sec(6,010 cfs). In general,there is very little relation between total basin precipitation and basinwide runoff. Figure 28 is a scatter plot of peak mean daily discharge vs. mean basinwide precipitation,which shows the wide scatter of points and correlation coefficient of 0.2297 ($r = 0.0527$) for this relationship. The largest storm event during the period of observation, $P = 4.57$ cm (1.80 in.), 8/1-8/5/1976,produced a peak mean daily discharge of only 61 cu.m/sec (2,160 cfs),which is less than one half of the mean annual daily discharge (136 cu.m/sec (4,813 cfs)).

The point of this comparison has to do with the question of sediment delivery. Sediment delivery of basinwide gross erosion and land wash to the gauge (a daily sediment record station) at Waterville has been estimated to be approximately 11% of gross erosion (GLBC, 1975).

4.48 Storms and Sediment Transport

Table 54 is taken from a report on nonpoint source pollution (Baker, 1976),which was prepared for the Toledo Metropolitan Area Council of Governments as part of an Areawide Water Quality Management Planning Study (PL 92-500 Sec. 208). Total flow, sediment,and phosphorus transport are summarized for eight storm events which occurred during 1975. Several large storms which occurred prior to April 25 are not included. Also, storms during August are not included because the automatic samplers had been taken out of service for other studies. During the unmeasured period,United States Geological Survey records indicate that storms on January 8 and February 22 produced the highest peak flows and sediment transport of individual storm events during the year.

The storms included in Table 54 are ranked according to total storm flow, total suspended solids mass transport,and flow weighted mean concentration of suspended solids. Most of the storms fall fairly well into order,with total flow rank corresponding with total load and flow weighted mean concentration rank. The greatest exception is the storm of Nov. 30,which ranked third in total volume of runoff but sixth and seventh in total suspended solids transport and flow weighted mean concentration. The major reason for the shift in rank order between total flow and solids transport is the association of this storm with snow-melt runoff.

Beginning on November 24 snow began accumulating on the ground at both Toledo and Ft. Wayne,reaching a maximum depth of 7.6 cm (3 in.) and 10.2 cm (4 in.) at each city, respectively,on November 27. Total liquid equivalent was 2.2 cm (0.72 in.) at Toledo and 1.0 cm (0.40 in.) at Ft. Wayne. Depth of snow on the ground at other stations in the Basin is unknown. By the beginning of rainfall precipitation on November 29,the snow depth at both cities had dropped to 2.5 cm (1.0 in.). By the time the rainfall had ended on November 30,there was no snow on the ground at either city.

The ratio of sediment transport between the storm of December 15 (the largest flow and sediment transport storm) and the snow-melt storm of November 24 is 17:1. The ratio of flows was 1.7:1. Antecedent moisture conditions were similar prior to both storms (wet). Soil was not

Figure 28. PEAK DISCHARGE VS STORM PRECIPITATION

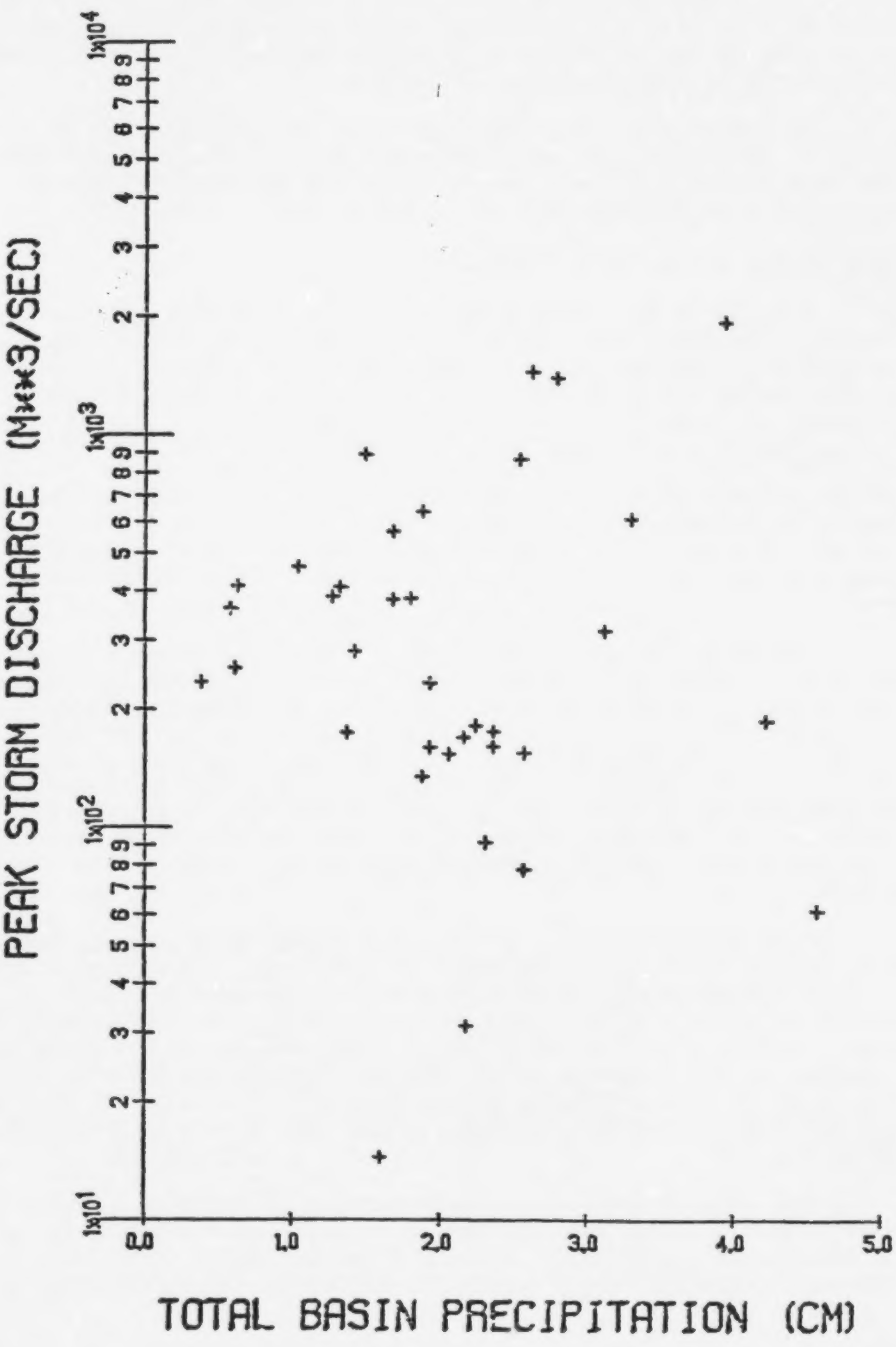


TABLE 54. PHOSPHORUS AND SUSPENDED SEDIMENT TRANSPORT DURING INDIVIDUAL STORM EVENTS OF 1975

Maumee River Dates		Total Phosphorus (TP)			Suspended Solids (SS)			mg of TP / g of SS	P_t	Rank Order of Storms			
Start	Finish	Flow (m^3)	Load (kg)	Wt. Mean Conc. (mg/1)	Flow (m^3)	Load (kg)	Wt. Mean Conc.			Q	Øss	[SS]	P_t
04/25	04/28	1.054×10^8	4.135×10^4	.3923	1.104×10^8	2.291×10^7	207.5	1.891	.58	5	4	6	8
05/21	05/25	1.760×10^8	1.427×10^5	.8108	1.759×10^8	8.363×10^7	475.4	1.706	1.30	2	3	3	3
06/05	06/07	8.570×10^7	3.730×10^4	.4352	8.570×10^7	2.290×10^7	267.2	1.629	.71	6	5	5	6
06/15	06/18	1.460×10^8	1.618×10^5	1.108	1.460×10^8	1.222×10^8	837.0	1.324	1.59	4	2	2	2
07/19	07/22	3.900×10^7	1.640×10^4	.4205	3.900×10^7	1.100×10^7	282.1	1.491	1.66	8	7	4	1
10/19	10/30	7.900×10^7	2.670×10^4	.3300	7.900×10^7	7.400×10^6	93.67	3.608	.81	7	8	8	5
11/30	12/06	1.550×10^8	7.140×10^4	.4606	1.540×10^8	1.480×10^7	96.10	4.793	.65	3	6	7	7
12/15	12/20	2.630×10^8	3.706×10^5	1.409	2.630×10^8	2.513×10^8	955.5	1.475	1.00	1	1	1	4

frozen in either case and basin cover conditions were probably identical, since the storms were separated by only two weeks.

Although it would be unwise to draw conclusions based on two storms, two observations can be made. The first observation is well known: rain falling on snow does not erode soil. The second has been the subject of considerable controversy and deals with the transport of eroded soils out of watersheds: does soil which enters the drainage network leave the watershed,or is it transported over a long period of time in a series of jumps with each successive runoff event? If the latter mechanism is the case,then the relationship between basin runoff and sediment transport should not be significantly altered by the fact that the runoff producing rain falls on snow. Sediment delivery to downstream stations should be more a function of channel velocity than the condition of the watershed at the time of rainfall, and the storm of November 29-30 should have transported 8 to 10 times as much sediment as it did. The observation then, based on the comparison of these two storms, is that sediment transported to a defined channel during a storm event probably moves completely out of the watershed during the storm in which it entered the drainage network.

4.49 Relationship of Gross Erosion and Sediment Delivery

Table 55 presents the estimated mean annual soil loss as determined for each of the experimental plots by the Universal Soil Loss Equation, the actual 2-year experimental mean annual sediment delivery and the sediment delivery ratio for each of the plots. The delivery ratio ranged from 6.3% on the Blount and Lenawee plots to 62% for the Paulding. The Blount soil had the coarsest texture and the Paulding the finest texture of the plots. The extremely high sediment delivery ratio of the very fine textured soils points to a need for special attention to these soils in management programs. Although gross erosion on these soils may be very low (and therefore are not flagged as "problem erosion areas"),their very high sediment delivery ratios make them a problem for Great Lakes water quality. The Paulding soil had absolutely the highest soil (and nutrient) loss of all the experimental plots.

Application of the "basin soil area weight" gives a basinwide gross erosion rate of 22.3 mt/ha/yr (10.0 t/a/yr) and 2.7 mt/ha/yr (1.01 t/a/yr) at the outlet of the plots, or a 12.3% sediment delivery ratio. This is further reduced to 0.94 mt/ha/yr in the Maumee River at Waterville, a delivery ratio of 4.2%. This estimate of gross erosion for the basin is probably overestimated. The Great Lakes Basin Commission (GLBC, 1975) estimated a basinwide gross erosion rate of 6.3 mt/ha/yr (2.8 t/a/yr), and the sediment delivery ratio with respect to this value is 14.9%. The true annual sediment delivery ratio probably lies somewhere between the two values: 4.2% to 14.9%. It must be remembered,though, as was pointed out in the discussion of monthly sediment delivery, that the sediment delivery ratio approaches 1 during the late winter/spring period and 0 during the summer months.

In the Portage River Basin the estimated annual gross erosion rate is 8.0 mt/ha/yr (3.5 t/a/yr) (TMACOG, 1976). As previously mentioned, this basin is quite homogeneous in soil type. The Hoytville soil series accounts for 43% of the basin. The Hoytville soil experimental plots are located in the Portage River basin near Hoytville, Ohio. The slope length on the plots is not representative of the slope length of the Hoytville soil series: plots 80 feet, basinwide around 500' and up to 1,200'.

TABLE 55. ESTIMATED ANNUAL GROSS EROSION RATES FOR PLOTS

SOIL TYPE	PLOT #	R	x	K	x	LS	x	C	x	P	=	A (T/A/Y)	(MT/HA/YR)	MEASURED SEDIMENT DELIVERY (MT/HA/YR)	DELIVERED RATIO (%)
ROSELMS	111	130		0.49		0.6		0.46		1.0	=	17.6	39.4	3.4	8.6
ROSELMS	201	130		0.49		0.33		0.46		1.0	=	9.7	21.7	4.7	21.7
LENAWEE	301	130		0.29		0.16		0.46		1.0	=	2.8	6.3	0.4	6.3
BLOUNT	401	130		0.43		0.8		0.46		1.0	=	20.6	46.1	2.9	6.3
PAULDING	501	130		0.49		0.16		0.46		1.0	=	4.7	10.5	6.5	61.9
HOYTVILLE	6_1	125		0.24		0.10		0.46		1.0	=	1.4	3.1	0.5	16.1
				BASINWIDE SOIL AREA WEIGHTED MEAN							=	10.0	22.3	2.7	12.3

The LS factor of the USLE would range to approximately double the plot LS factor, or up to about 0.2 The fact that the plots were all underdrained is also considered to have significantly reduced gross erosion. The two-year mean annual soil loss from the plots was about 0.5 mt/ha/yr compared to the USLE estimated gross erosion rate (not considering tile drainage) of 3.1 mt/ha/yr, or about 16% sediment delivery ratio. Sediment delivery for the Portage River basin during 2-1/2 years of monitoring averaged 0.53 mt/ha/yr, virtually the same value as at the outlet of the plots. The sediment delivery ratio of the basin (estimated basinwide gross erosion vs. measured sediment delivery) was 6.3%.

4.410 Utility for Extrapolation

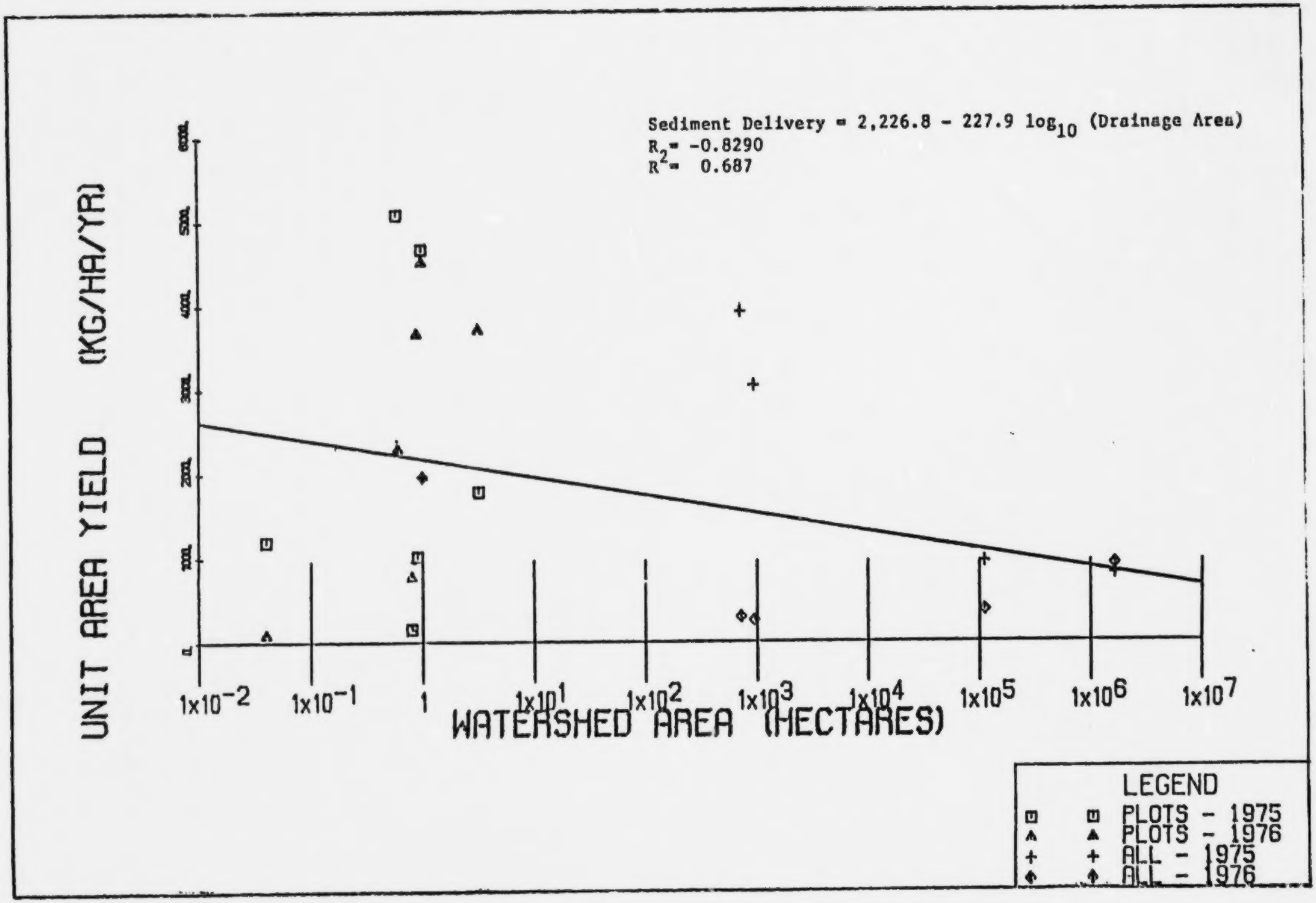
One of the principal objectives of the Task C - Pilot Watershed Studies is to provide information which can be used to extend the knowledge gained in those studies to unstudied (or unmeasured) areas of the Great Lakes watershed. The problem of extrapolating data obtained in land runoff studies over a period of little more than two years to a general case must be considered tenuous. That is the caveat which must be expressed with the presentation of this information.

Much of the information useful for extrapolation to other areas has been presented in detail elsewhere in this report. Sediment and nutrient yields from specific soil types and their seasonal variations have been discussed in detail. The discussion of measured yields in relation to estimated gross erosion rates in conjunction with soil physical and chemical properties should be particularly useful. The parameters of the USLE given for the experimental plots should enable other investigators to relate to the nature of the plots. Taking into account the other soil properties presented,others should be able to determine how these results compare to the work they are doing and how to improve nutrient and sediment delivery estimates being made for other watershed areas.

A commonly utilized extrapolation parameter is the relationship between drainage basin size and sediment yield. Many different forms of regression analysis were attempted to determine such a relationship for the Maumee River Basin studies. It had been hoped that a drainage area/sediment yield relationship could be determined within seasons for the Maumee subbasins, but this was made impossible because short-term variations in rainfall patterns, snow melt, antecedent moisture, etc. caused much more of the variance in the data than the difference in watershed size. Within months,sediment and nutrient yields were virtually independent of drainage basin size.

The best relationship between yield and watershed area was found to be between study period mean annual yield and $\log_{10}$ drainage basin size. The regression line for this relationship is shown in Figure 29 . The points plotted are not the points which determine the regression. The regression line is determined by the 2 to 2-1/2 year mean annual sediment yield and $\log_{10}$ of the drainage basin size. The effects of meteorological variations are significantly reduced as is the variance among drainage basin sizes. The regression line is determined from the following data set:

FIGURE 29. SEDIMENT YIELDS AS A FUNCTION OF DRAINAGE AREA



Sediment Delivery = 2,226.8 − 227.9 $\log_{10}$ (Drainage Area)
R_2= −0.8290
R^2= 0.687

	Drainage Area (Hectares)	$\log_{10}$ D.A. ($\log_{10}$ Hectares)	Sediment Delivery (kg/ha/yr)
Plots	1.0	0.	1,968
Black Creek Site 6	714	2.855	2,107
Black Creek Site 2	942	2.974	1,646
Portage River	110,900	5.045	658
Maumee River	1,639,500	6.215	860

Regression of Sediment Delivery and $\log_{10}$ (Drainage Area):

Sediment Delivery   2,226.8 - 227.9$\log_{10}$ (Drainage Area)

$R = -0.8290 \quad R^2 = 0.687$

The points plotted in Figure 29 represent (see legend) single-year sediment yields from each of the study area watersheds. Also, the + (plus) and ◇ (diamond) symbols at 1.0 hectares (they are superimposed on one another at 1976 kg/ha/yr and 1975 kg/ha/yr, respectively) represent the soil area weighted mean of the plot sediment yields,which are individually represented by the □ (square) and △ (triangle) symbols.

A similar regression was performed for total phosphorus yield based on the same criteria (two-year mean annual total phosphrous yield):

Area (Hectares)	Total Phosphorus Yield kg/ha/yr
1.0	2.284
714	2.838
942	3.658
110,900	0.938
1,639,500	1.629

Total P Yield (kg/ha/yr) = 3.229 = 0.263$\log_{10}$ Area (Hectares)

$R = -0.5901 \quad R^2 = 0.348$

It is apparent that total phosphorus yield is less dependent on drainage basin size than is sediment delivery. It has been shown that runoff sediment is enriched with clay-size particles relative to the soil from which it originated. Runoff sediment had clay content ranging from 53 to 96%,while the surface soils ranged from 27 to 56%. Suspended sediments in the Maumee River at Waterville are 74% total clay (USGS, 1972), indicating further enrichment of the runoff sediment with increasing drainage basin size. It was also shown that the clay fraction is enriched with phosphorus relative to the surface soils. It is therefore apparent that as the clay-size fraction is preferentially transported to the main stem of the river, phosphorus is also preferentially transported to the mouth.

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6. APPENDIX

Analytical Methods and References

Analysis	Method	Reference
1. pH	Glass electrode; 1:1 soil-water and soil - 0.01M $CaCl_2$	---
2. Organic carbon	Dry combustion	Winters, E., and R. S. Smith. 1929. Ind. Eng. Chem. Anal. Ed. 1:202-203.
3. Electrical Conductivity	Conductance meter	USDA Handbook 60. 1954. Diagnosis and Improvement of Saline and Alkali Soils.
4. Dissolved oxygen	Probe	Methods for Chemical Analysis of Water and Wastes. EPA. 1971.
5. Calcite + dolomite	Gasometric with Chittek apparatus	Dreimanis, A. 1962. J. Sediment, Petrol. 32:520-529.
6. Carbonates + Bicarbonates	Titration with HCl	Methods of Soil Analysis. 1965. Amer. Soc. Agron. Mono. 9. Para 62 - 3-4
7. Cation exchange capacity	Sum of exchangeable bases plus hydrogen. Hydrogen by TEA-$BaCl_2$ pH 8.2	Methods of Soil Analysis. Amer. Soc. Agron. Mono. 9. 1965. Para 57-4
8. Cation exchange capacity for clays	Saturate with 1N $BaCl_2$ and determine Ba by X-ray fluorescence	---
9. Particle size distribution	Pipet method	Methods of Soil Analysis. Amer. Soc. Agron. Mono. 9. 1965. Para 43-4
10. Soil fractionation	Sedimentation	Rutledge, E. M., L. P. Wilding, M. Elfield. 1967. Soil Sci. Soc. Amer. Proc. 31:287.
11. BOD	Modified Winkler Method	Methods for Chemical Analysis of Water and Wastes. EPA. 1971.

	Analysis	Method	Reference
12.	Amorphous Fe and Al	Acid ammonium oxalate extraction	Saunders, W. M. H., 1965. New Zeal. J. Agr. Res. 8:30-57.
13.	Amorphous Si	Alkali dissolution	Hashimoto, I. and M. L. Jackson. 1960. Clays and Clay Minerals. 7th Conf. 102-113. Pergamon Press.
14.	Free Fe and Al oxides	Citrate-dithionate-bicarbonate extraction	Mehra, O. P. and M. L. Jackson. 1960. Clays and Clay Minerals. 7th Conf. 317-327. Pergamon Press.
15.	Phosphorus adsorption capacity	Langmuir adsorption isotherm	Olsen, S. R. and F. S. Watanabe. Soil Sci. Soc. Amer. Proc. 21:144-148.
16.	Total N	Kjeldahl digestion	Methods of Soil Analysis. Amer. Soc. Agron. Mono. 9, 1965. Para 83-4.
17.	Organic N	Total-inorganic $N(NH_4 + NO_3)$	---
18.	Ammonia	Steam distillation with MgO	Methods of Soil Analysis. 1965.
19.	Nitrate	Steam distillation with MgO and Devarda's alloy	Amer. Soc. Agron. Mono. 9, Para 84-3.
20.	Total P*	Perchloric acid digestion	ASA Mono. 9, Para 73-2.
21.	Org. P*	Ignition method	ASA Mono. 9, Para 73-3.
22.	Inorganic P	Ascorbic acid-reduced phosphomolybdate	Murphy, J. and J. P. Riley. 1962. Anal. Chim. Acta. 27:31-36.
23.	Available P*	Bray P1 extraction	Bray, R. H. and L. T. Kurtz. 1945. Soil Sci. 59:39-45.
24.	Exchangeable cations	Replace with 1N $BaCl_2$	---
25.	Potassium, sodium	Emission spectroscopy	---
26.	Calcium, magnesium	Atomic absorption spectroscopy	---

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* P measured by asorbic acid - reduced phosphomolybdate as in item 22.

	Analysis	Method	Reference
27.	Chloride	$AgNO_3$ titration	USDA Handbook No. 60. 1954. Diagnosis and Improvement of Saline and Alkali Soils.
28.	Si, Fe, Al	Atomic absorption	---
29.	Total K, Fe	X-ray fluorescence	Wilding, L. P., L. R. Drees, N. E. Smeck and G. F. Hall. 1971. Till: A Symposium. R. P. Goldthwait, Ed. Ohio State Univ. Press. Pgs. 290-317.
30.	Total Al, Si	HF digestion. Al and Si analysis by atomic absorption	---
31.	Trace Metals	Atomic absorption	---
32.	Pesticides	Gas chromatography	---
33.	Mineralogy	X-ray diffraction	Wilding, L. P., L. R. Drees, N. E. Smeck and G. F. Hall. 1971. Till: A Symposium, R. P. Goldthwait, Ed. Ohio State Univ. Press. Pgs. 290-317.